US005241347A

United States Patent [19]

Kodama

[11] Patent Number: 5,241,347

[45] Date of Patent: Aug. 31, 1993

[54] IMAGE FORMING APPARATUS COMPRISING MEANS FOR AUTOMATICALLY ADJUSTING IMAGE DENSITY

[75] Inventor: **Hideaki Kodama**, Okazaki, Japan

[73] Assignee: **Minolta Camera Kabushiki Kaisha**, Osaka, Japan

[21] Appl. No.: **799,295**

[22] Filed: **Nov. 27, 1991**

[30] **Foreign Application Priority Data**

Nov. 29, 1990 [JP] Japan 2-335845

[51] **Int. Cl.**^{5} **G03G 21/00**

[52] **U.S. Cl.** **355/246**; 346/160; 355/208

[58] **Field of Search** 355/246, 245, 203, 204, 355/208, 206, 209; 346/160

[56] **References Cited**

U.S. PATENT DOCUMENTS

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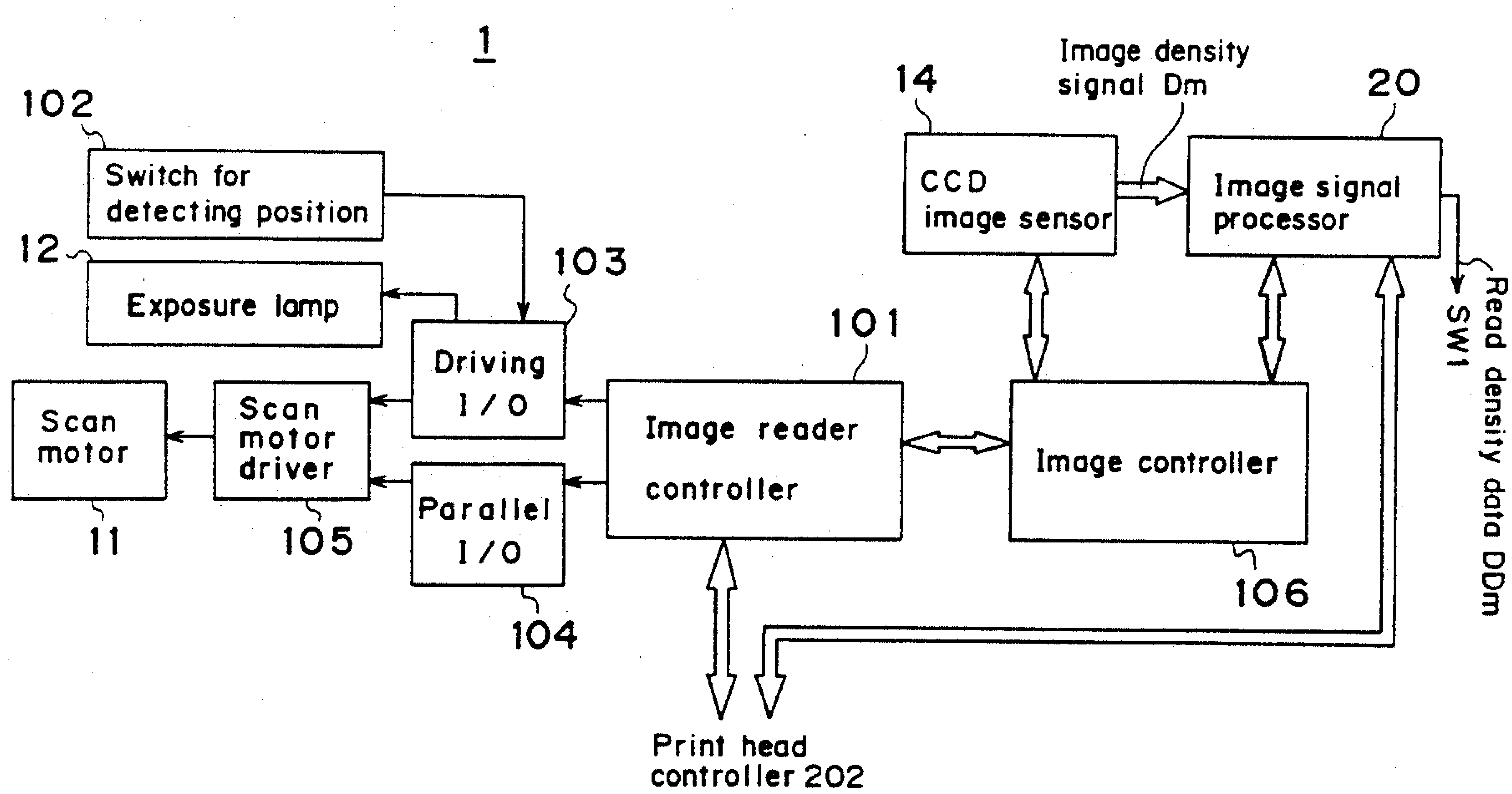
4,627,712	12/1986	Usami	355/206
4,693,592	9/1987	Kurpan	355/208
4,733,276	3/1988	Kakitani	355/246 X
4,829,336	5/1989	Champion et al.	355/246
4,833,506	5/1989	Kuru et al.	355/208
4,853,738	8/1989	Rushing	355/327
4,873,428	10/1989	Takeuchi et al.	250/214 DC
4,959,669	9/1990	Haneda et al.	346/157
5,012,286	4/1991	Kawano et al.	355/246
5,045,883	9/1991	Ishigaki et al.	355/246 X

Primary Examiner—A. T. Grimley
Assistant Examiner—Sandra L. Brasé
Attorney, Agent, or Firm—Burns, Doane, Swecker & Mathis

[57] **ABSTRACT**

In an image forming apparatus for forming an image on a sheet of paper, including an image forming device for forming a reference toner image having a predetermined density on an image retaining member. A first detector detects a density of the reference toner image formed on the image retaining member and outputs first density data for representing the detected density thereof, and then, the reference toner image formed on the image retaining member is transferred onto a sheet of paper. On the other hand, a second detector detects a density of the reference toner image transferred on the sheet of paper and outputs second density data for representing the detected density thereof. Further, a controller automatically adjusts an image density of an image formed on a sheet of paper so as to obtain a predetermined image density by controlling operation conditions of the image forming device based on the first and second density data respectively outputted from the first and second detectors.

9 Claims, 30 Drawing Sheets



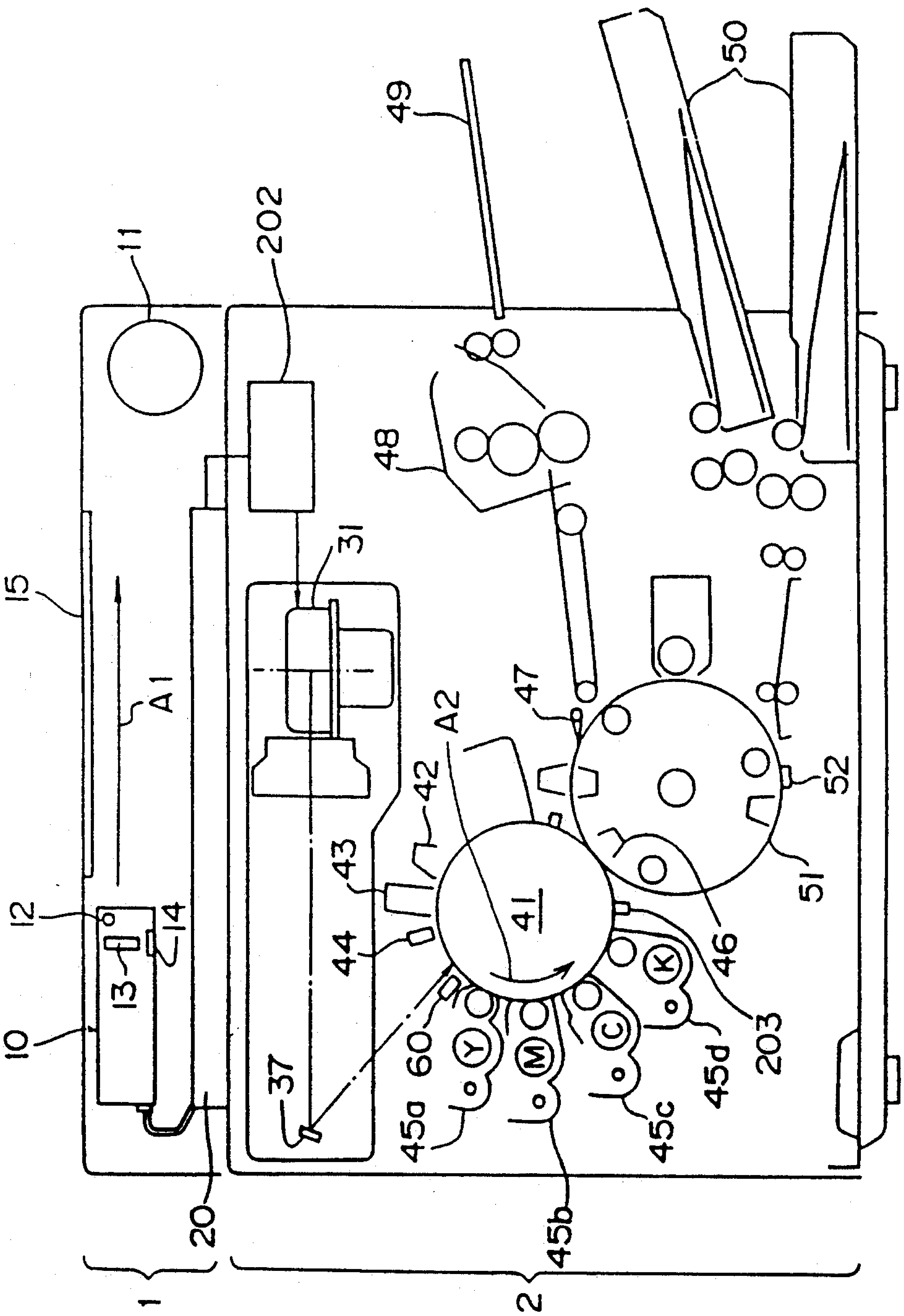

1
2
10
11
12
13
14
15
20
A1
202
31
37
41
42
43
44
A2
45a
45b
45c
45d
Y
M
C
K
46
47
48
49
50
51
52
60
203

Fig. 1

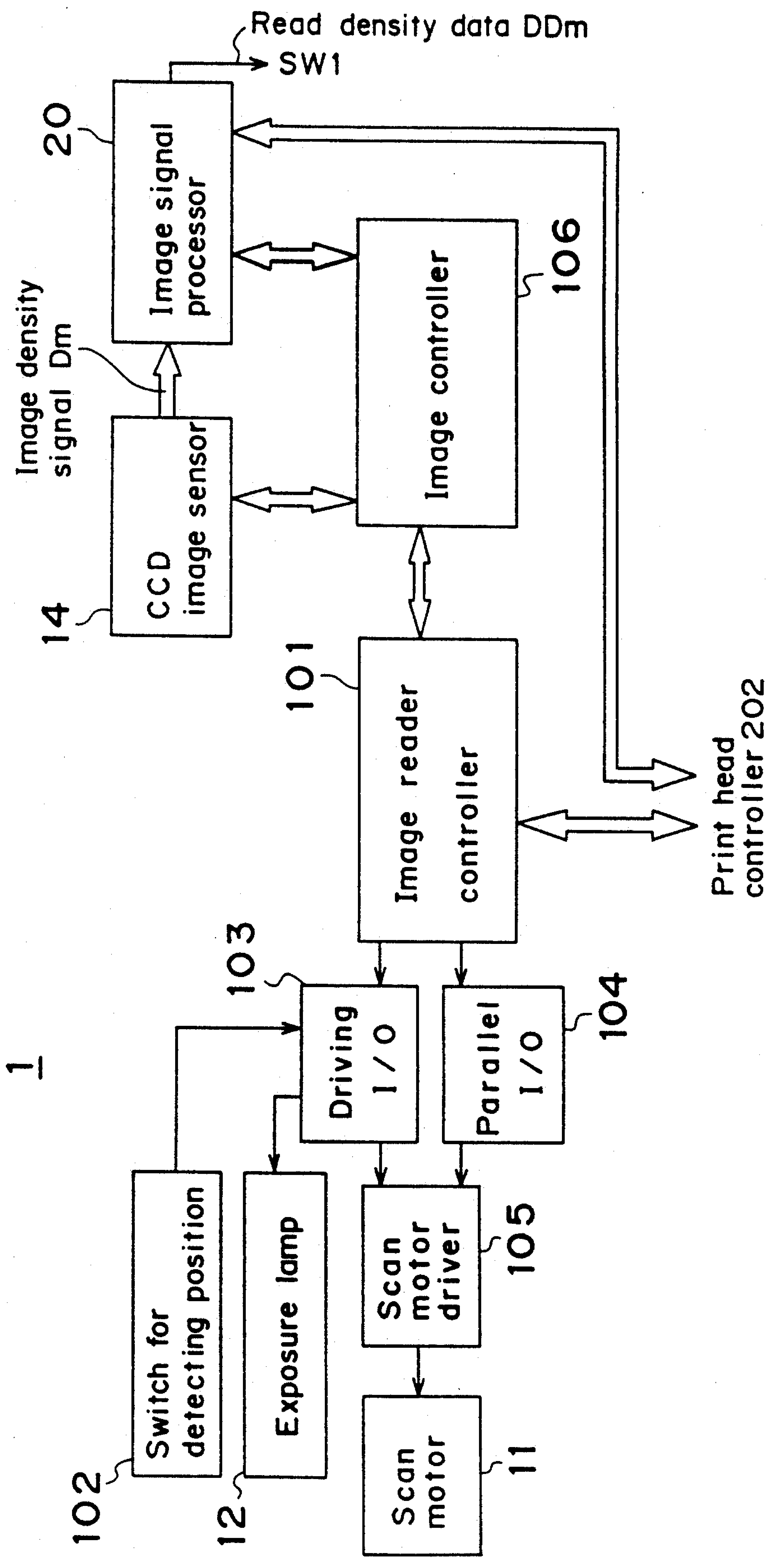
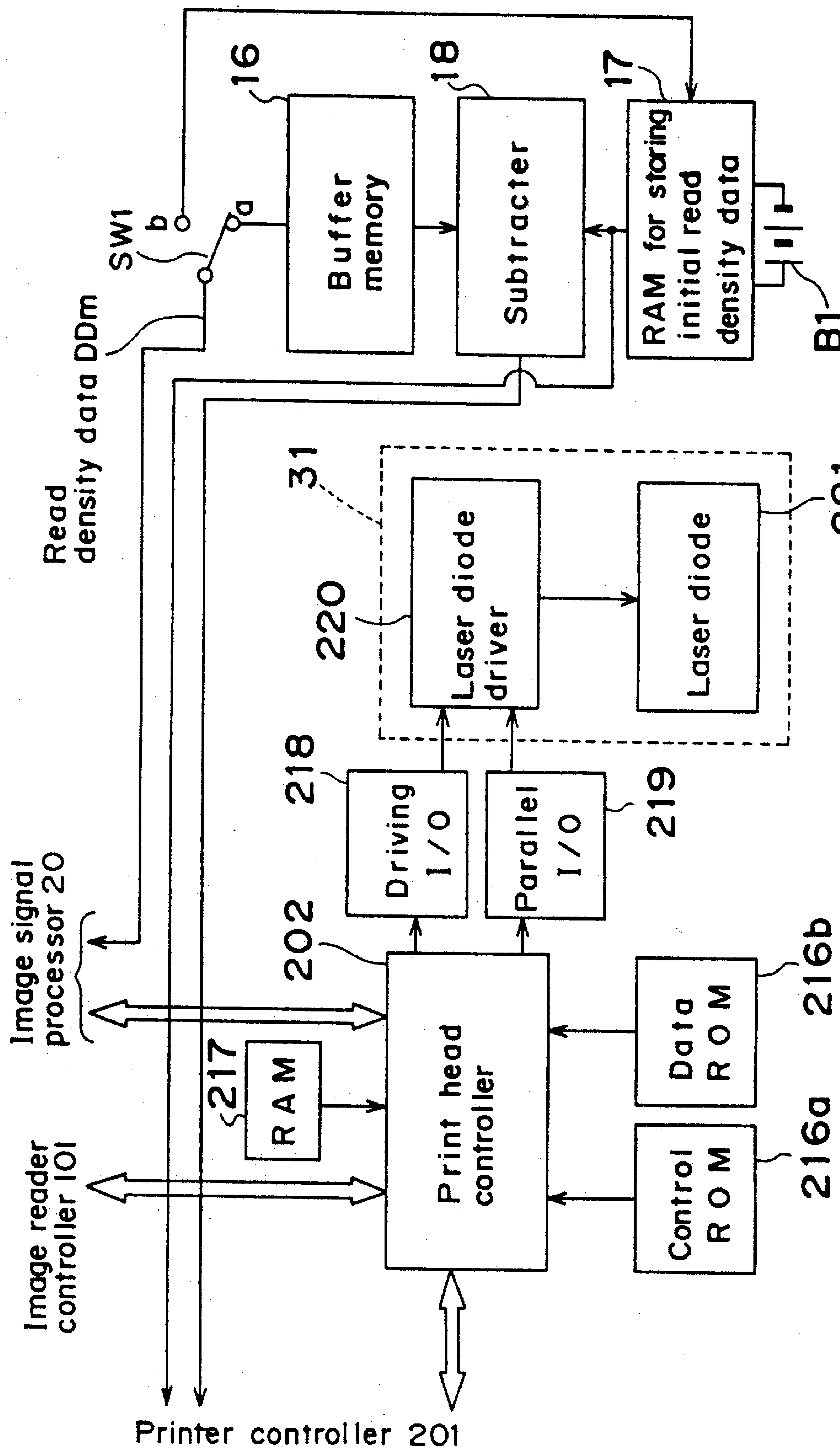
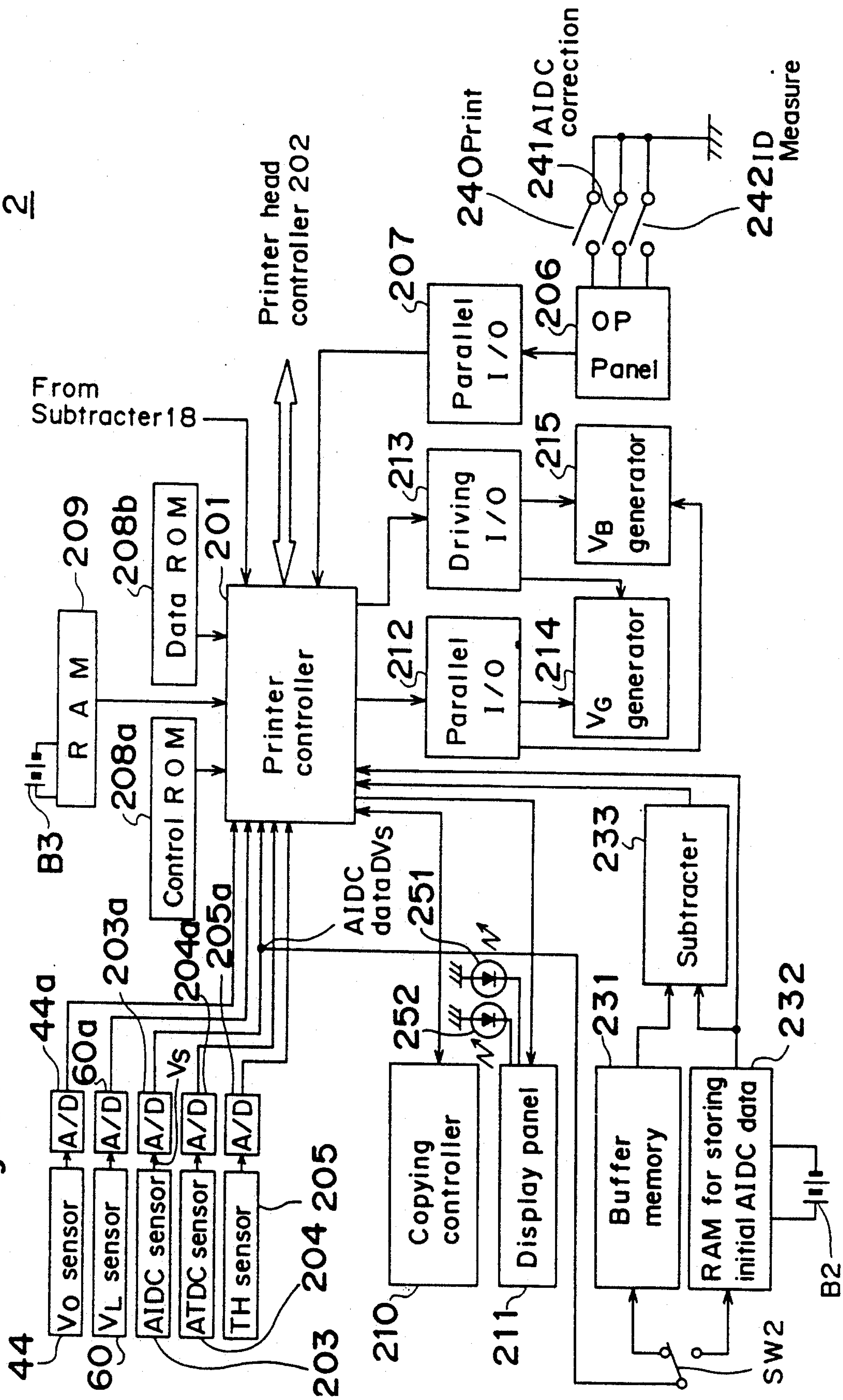

Read density data DDm
SW1
20
Image signal processor
Image density signal Dm
14
CCD image sensor
Image controller
106
101
Image reader controller
Print head controller 202
1
103
Driving I/O
Parallel I/O
104
102
Switch for detecting position
12
Exposure lamp
Scan motor driver
105
Scan motor
11

Fig. 2a



2
Image signal processor 20
Image reader controller 101
Printer controller 201
Read density data DDm
SW1
a
b
16
Buffer memory
18
Subtracter
17
RAM for storing initial read density data
B1
31
220
Laser diode driver
221
Laser diode
218
Driving I/O
219
Parallel I/O
202
Print head controller
217
RAM
216b
Data ROM
216a
Control ROM

Fig. 2b



2
Printer head controller 202
From Subtracter18
209
R A M
B3
208b
Data R O M
208a
Control R O M
201
Printer controller
207
Parallel I/O
206
OP Panel
240Print
241AIDC correction
242ID Measure
213
Driving I/O
215
VB generator
212
Parallel I/O
214
VG generator
233
Subtracter
AIDC data DVs
251
252
44a
60a
203a
204a
205a
Vs
A/D
Vo sensor
VL sensor
AIDC sensor
ATDC sensor
TH sensor
44
60
203
204
205
Copying controller
210
Display panel
211
231
Buffer memory
232
RAM for storing initial AIDC data
B2
SW2

Fig. 2c

Fig. 3

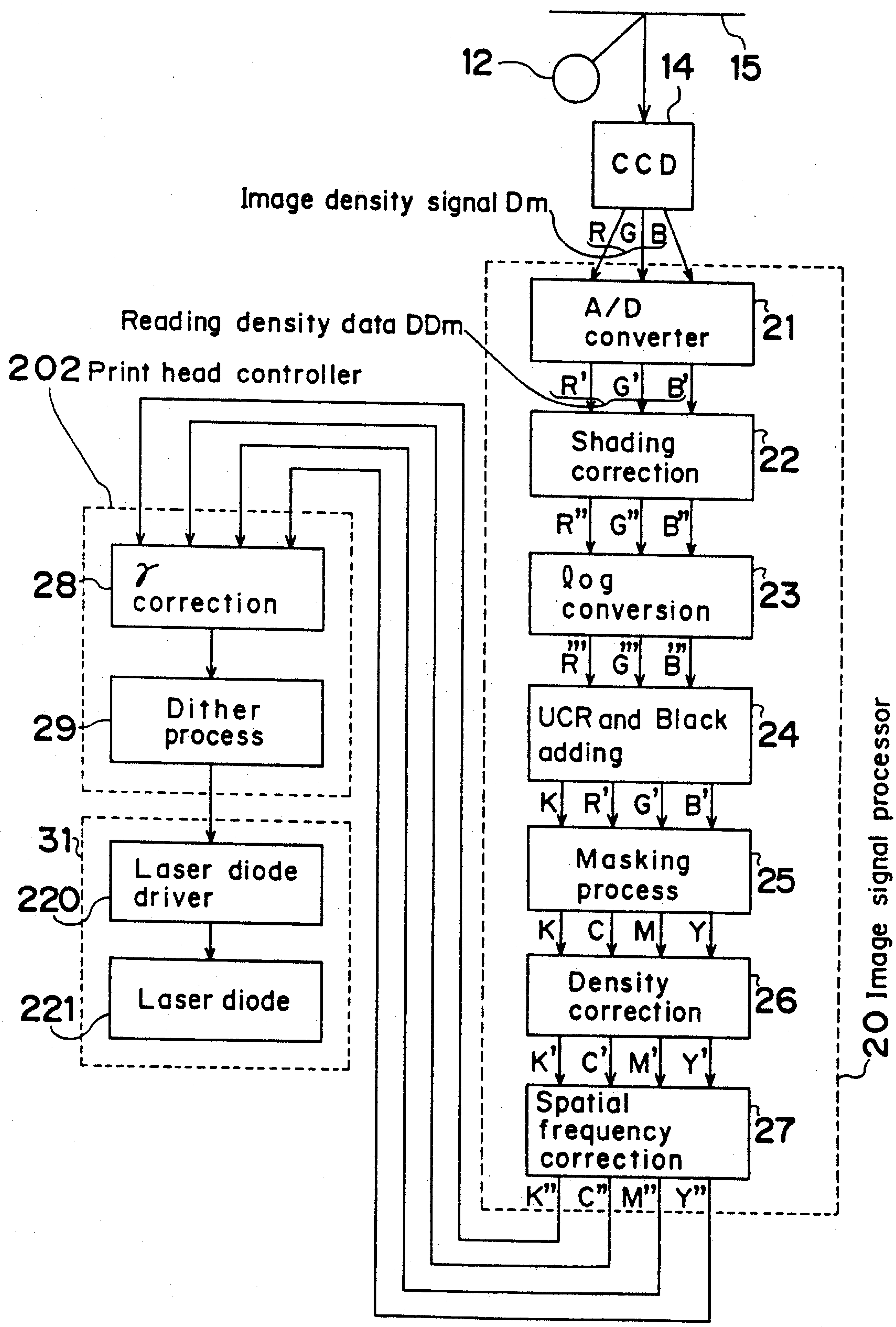

12
14
15
CCD
Image density signal Dm
R G B
A/D converter
21
Reading density data DDm
R' G' B'
Shading correction
22
202 Print head controller
R" G" B"
log conversion
23
R''' G''' B'''
UCR and Black adding
24
K R' G' B'
Masking process
25
K C M Y
Density correction
26
K' C' M' Y'
Spatial frequency correction
27
K" C" M" Y"
20 Image signal processor
28
γ correction
29
Dither process
31
220
Laser diode driver
221
Laser diode

Fig. 4 PRIOR ART

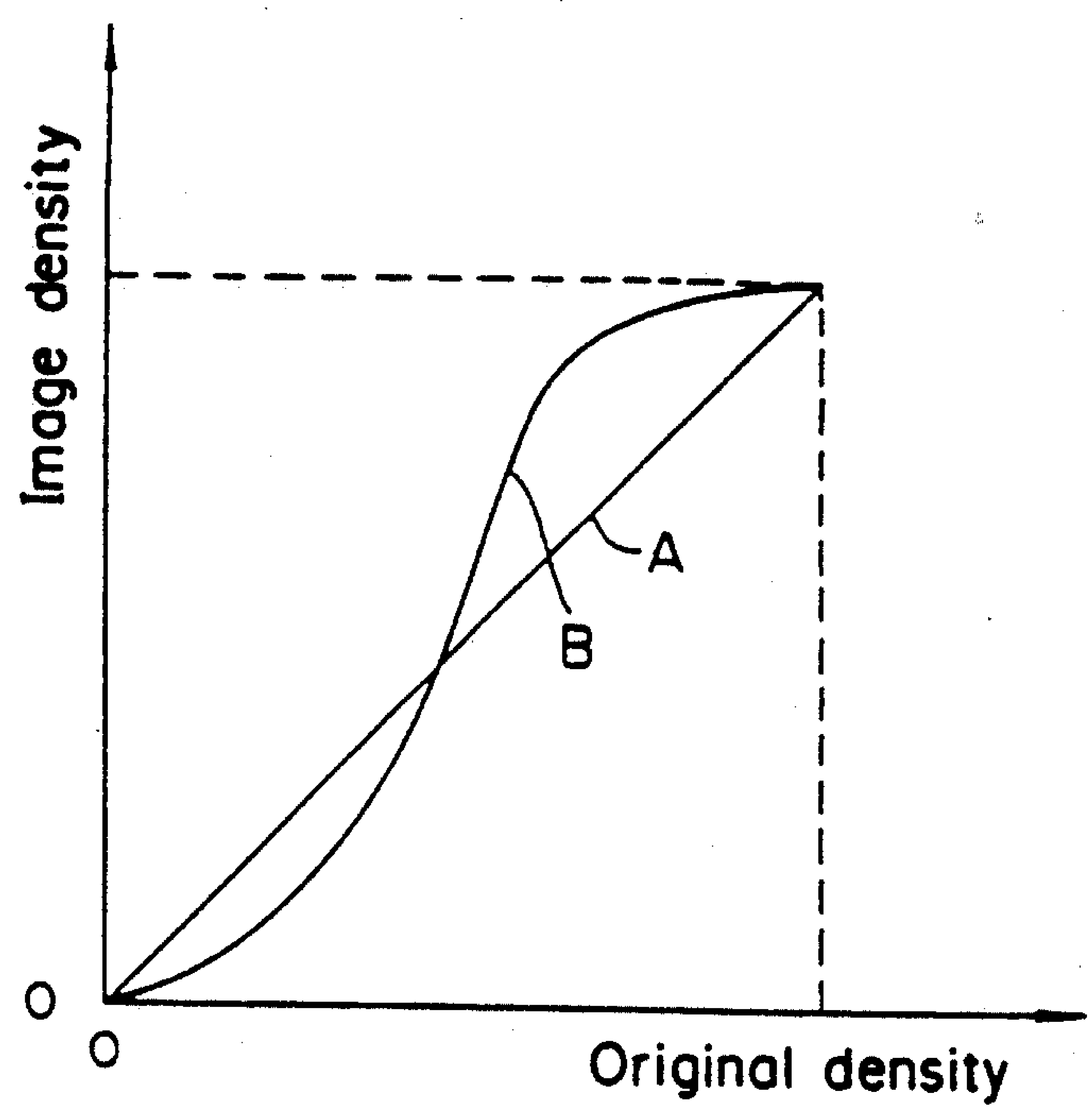


Fig. 5 PRIOR ART

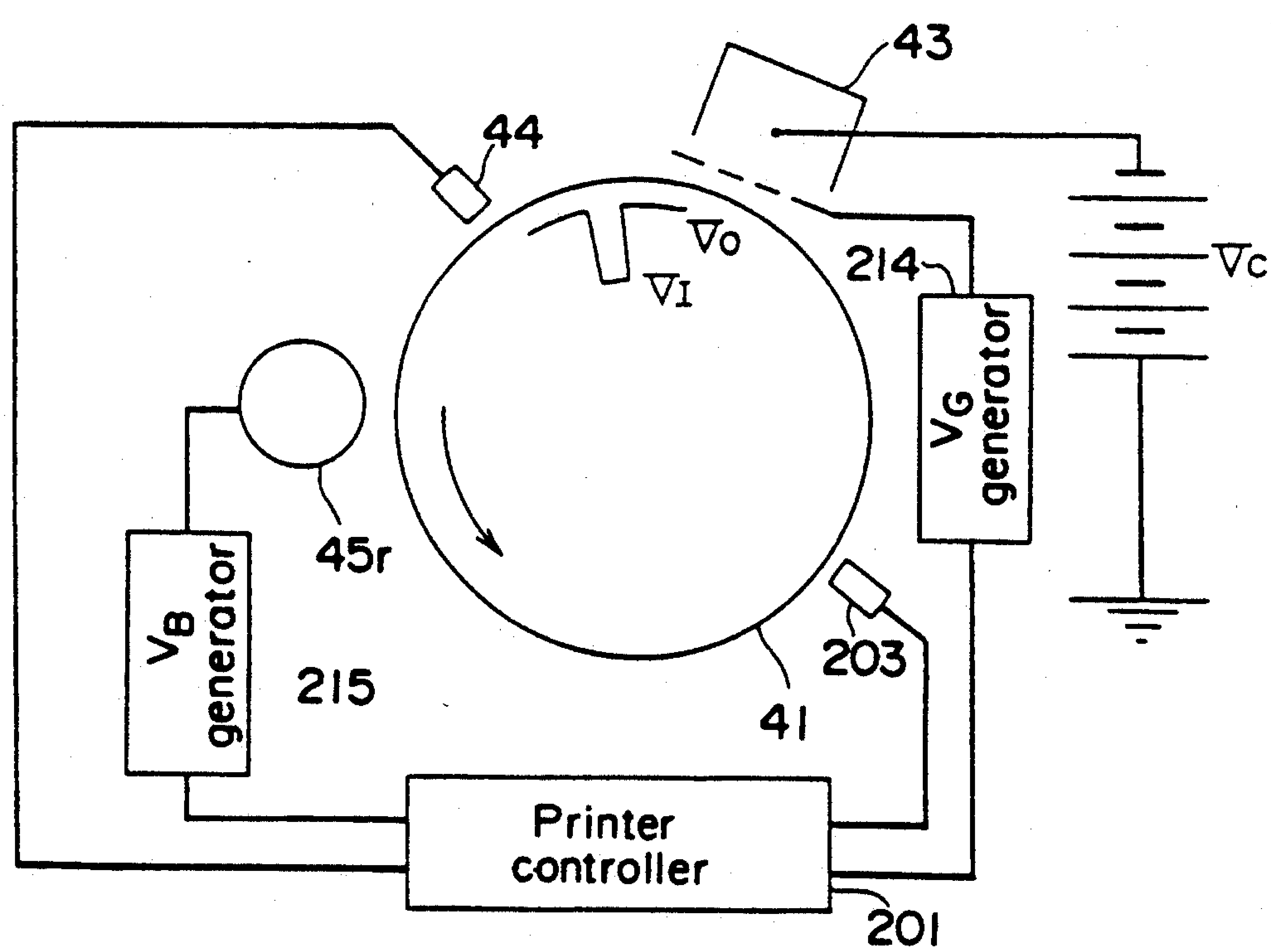


Fig. 6

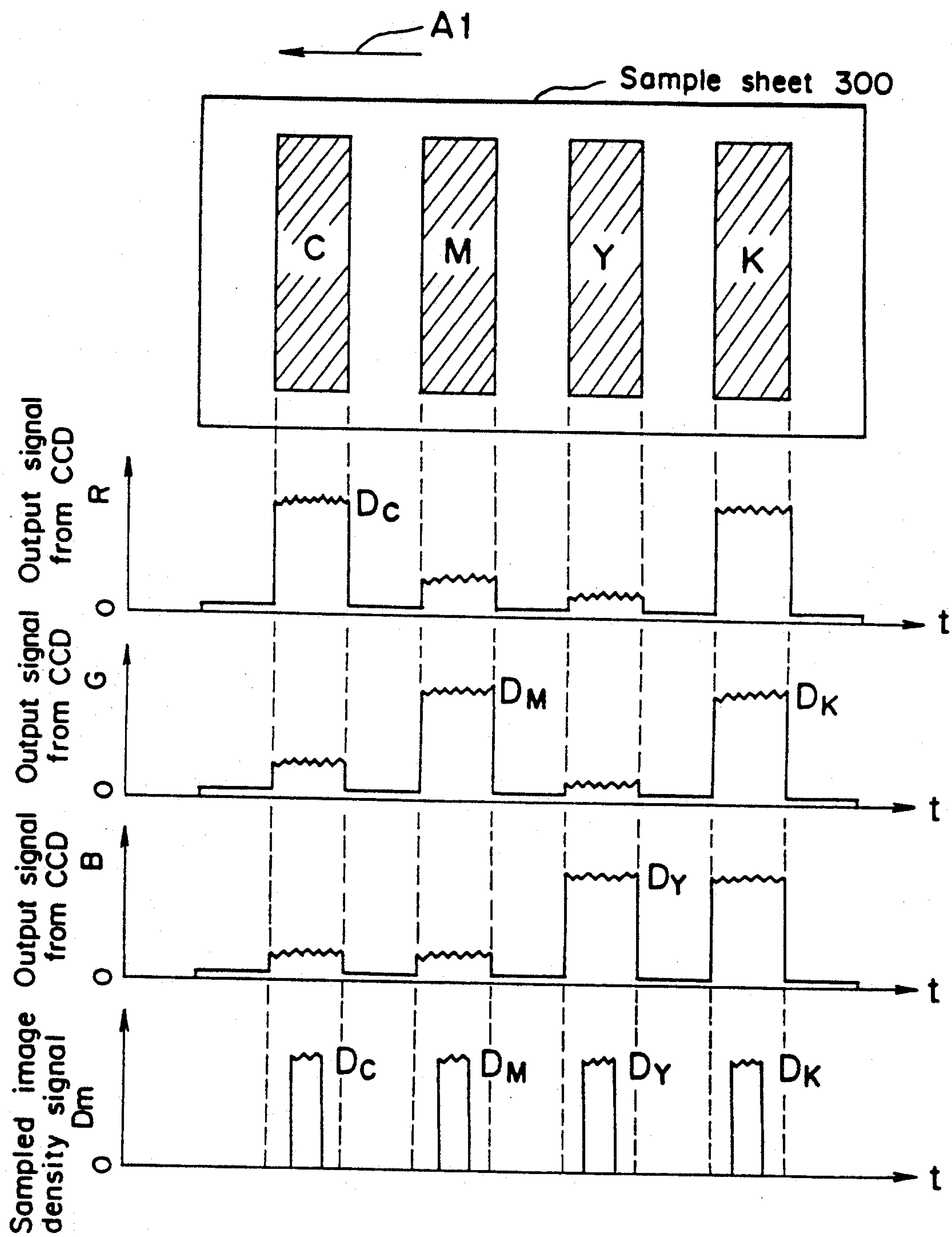

A1
Sample sheet 300
C
M
Y
K
Output signal from CCD R
0
Dc
t
Output signal from CCD G
0
DM
DK
t
Output signal from CCD B
0
DY
t
Sampled image density signal Dm
0
Dc
DM
DY
DK
t

Fig. 7

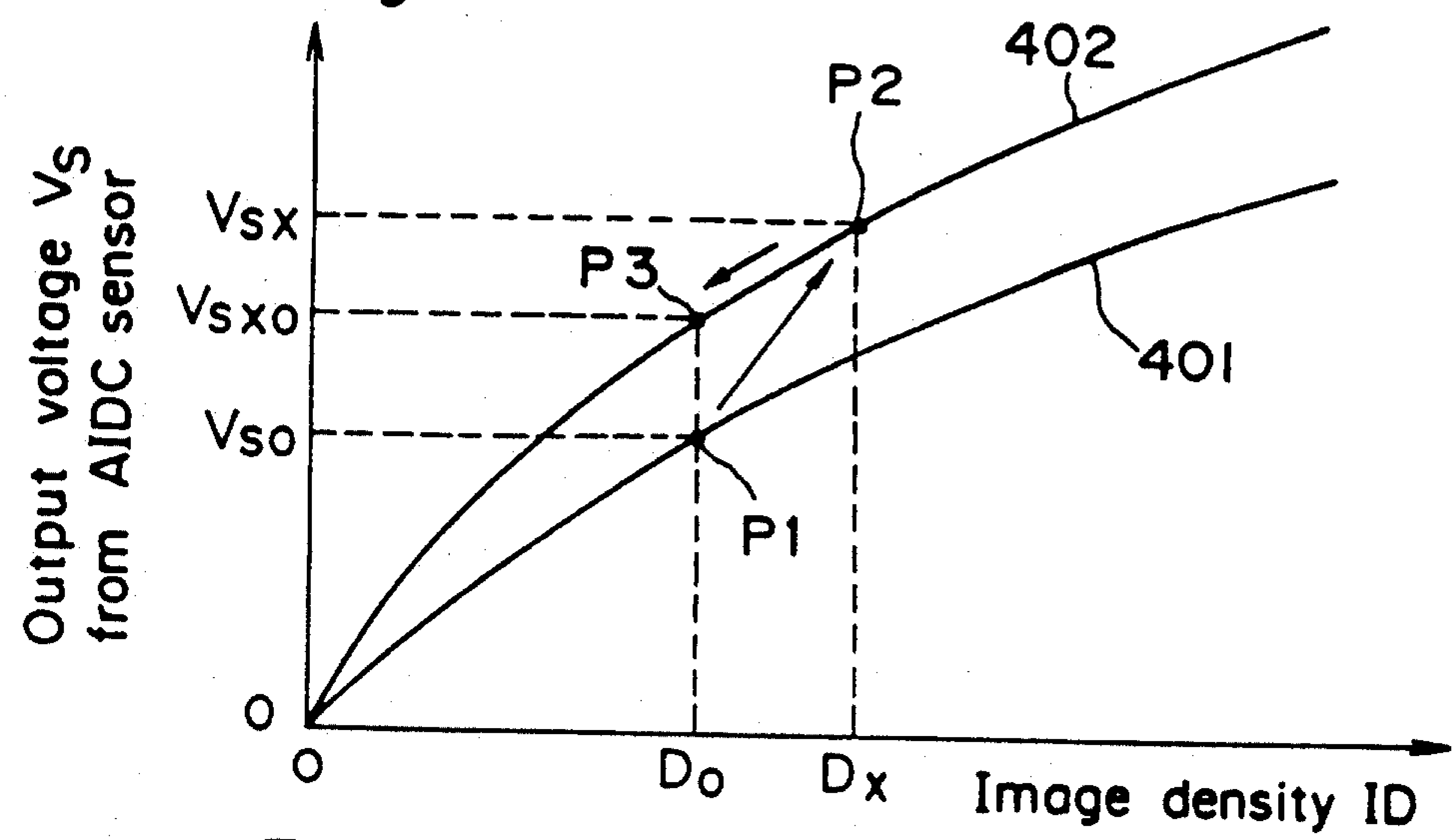


Fig. 8

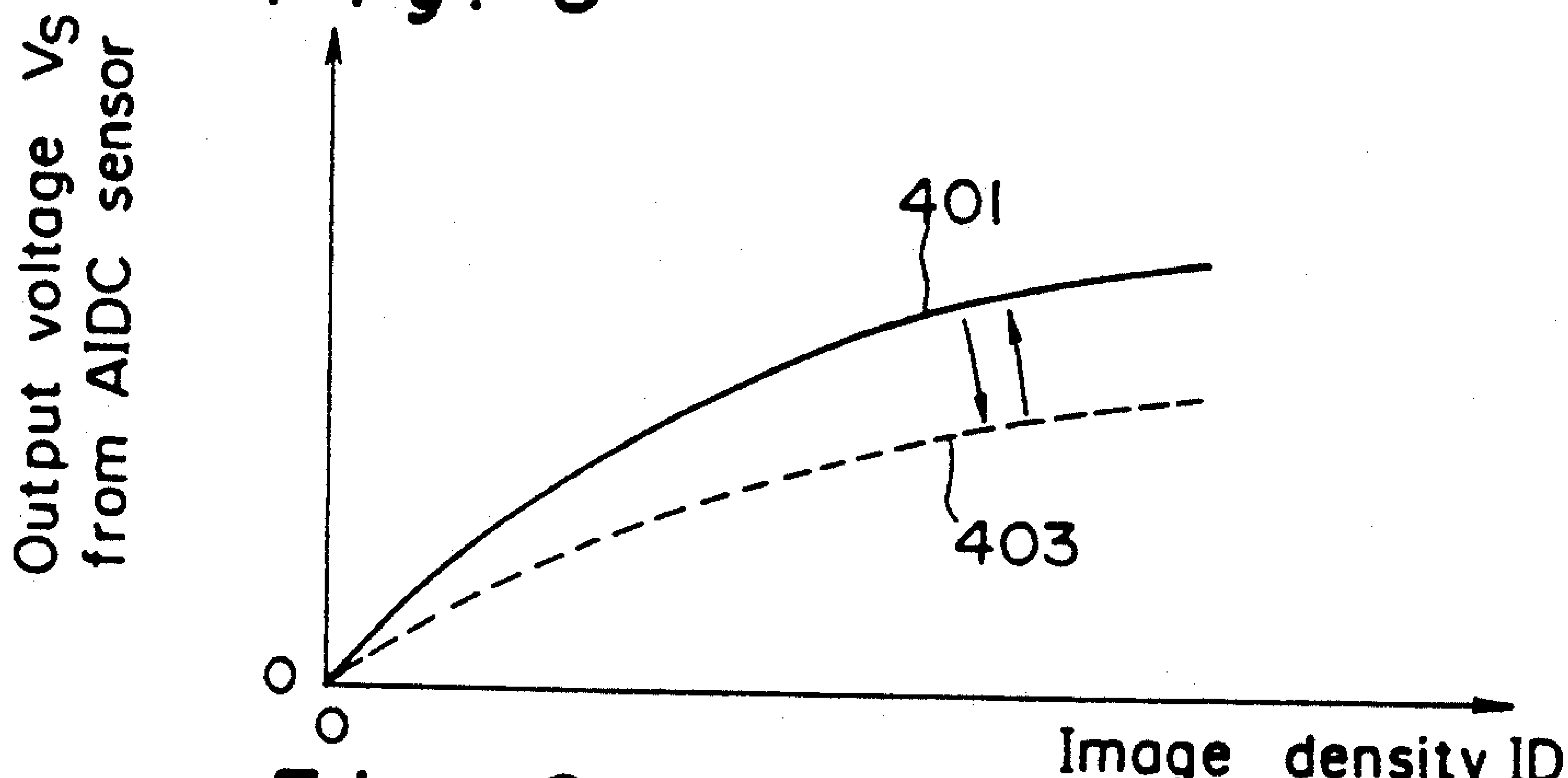


Fig. 9

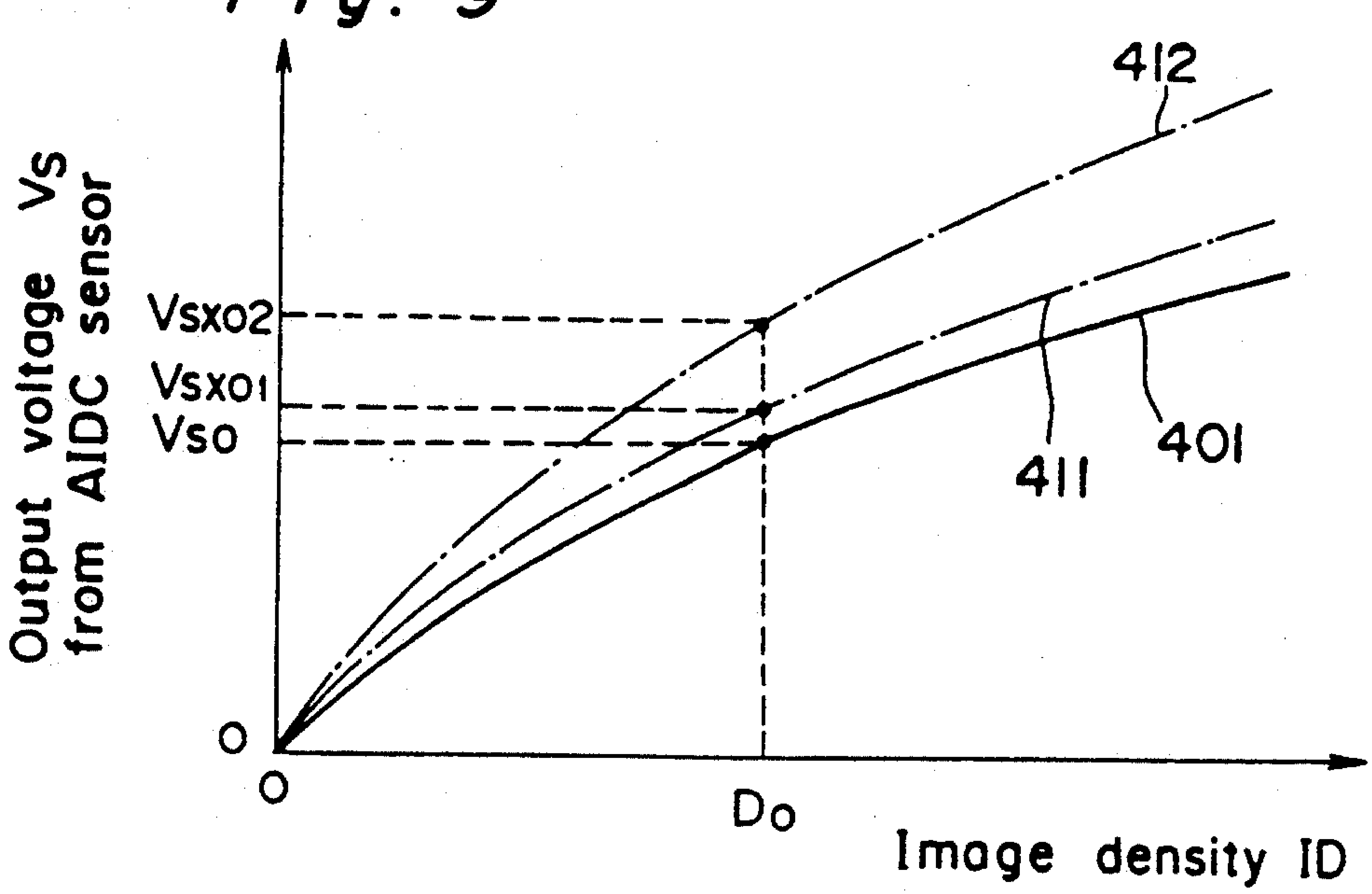


Fig. 10a

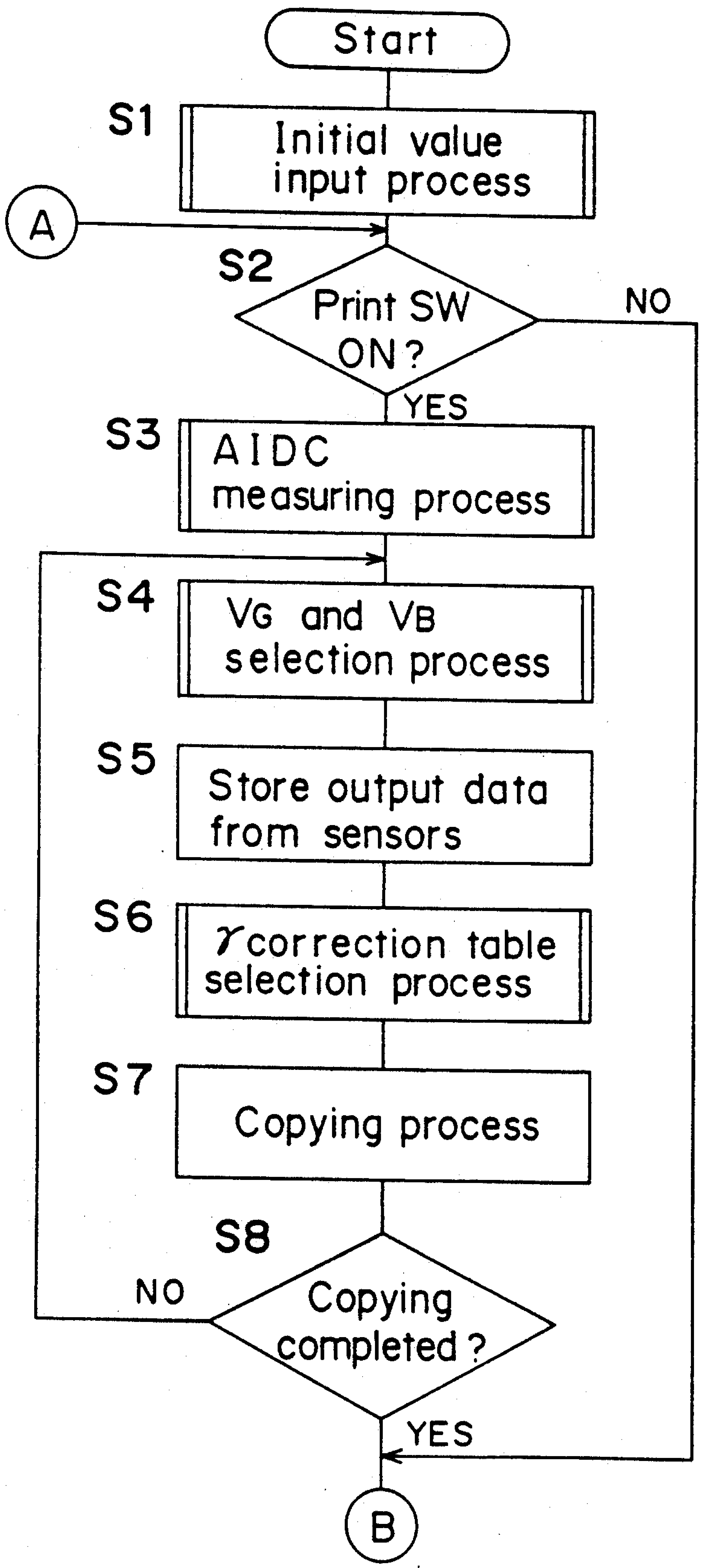

Start
S1
Initial value input process
A
S2
Print SW ON?
NO
YES
S3
AIDC measuring process
S4
VG and VB selection process
S5
Store output data from sensors
S6
γ correction table selection process
S7
Copying process
S8
Copying completed?
NO
YES
B

Fig. 10b

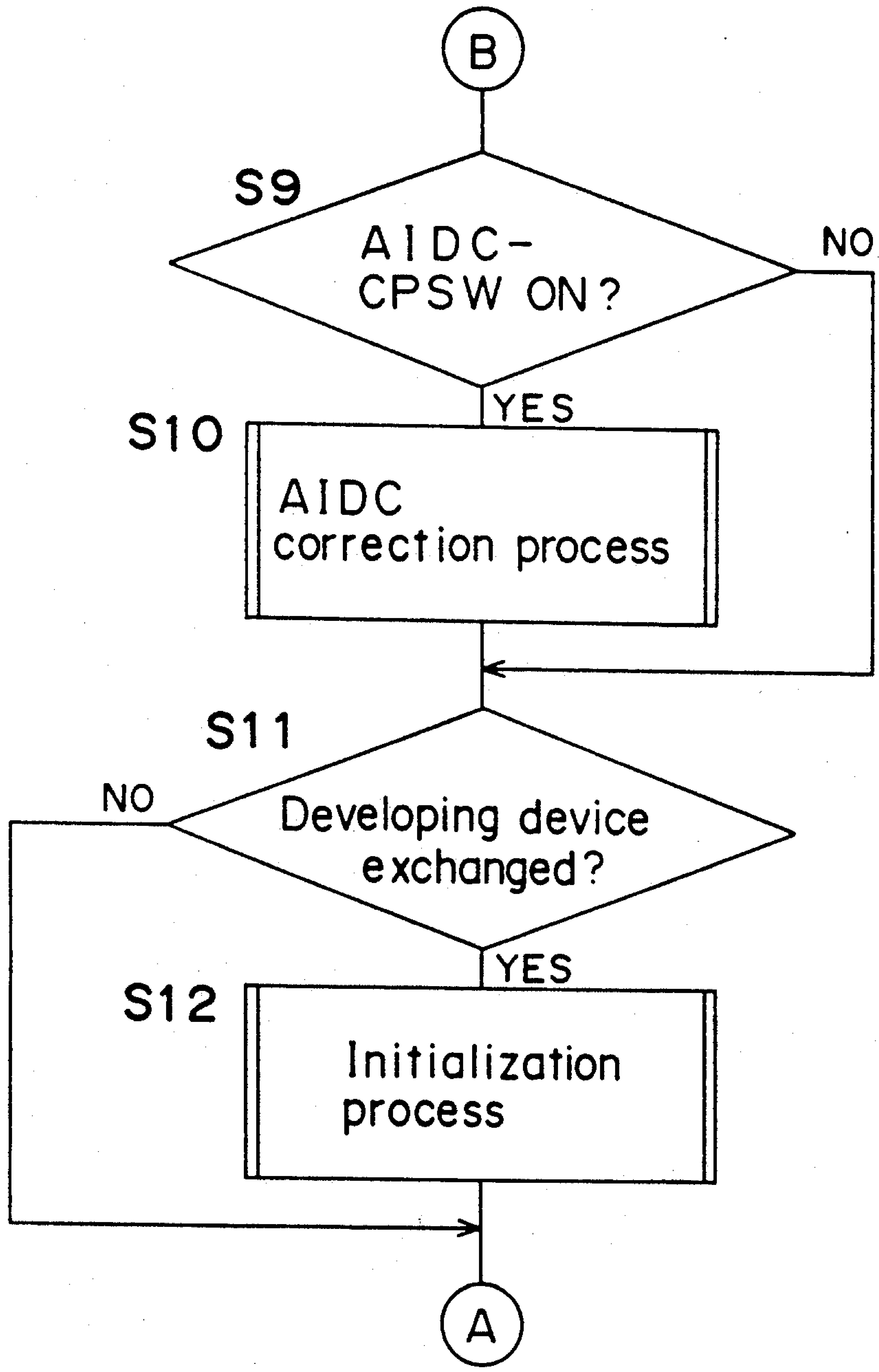

B
S9
AIDC-
CPSW ON?
NO
YES
S10
AIDC
correction process
S11
NO
Developing device
exchanged?
YES
S12
Initialization
process
A

Fig. 11

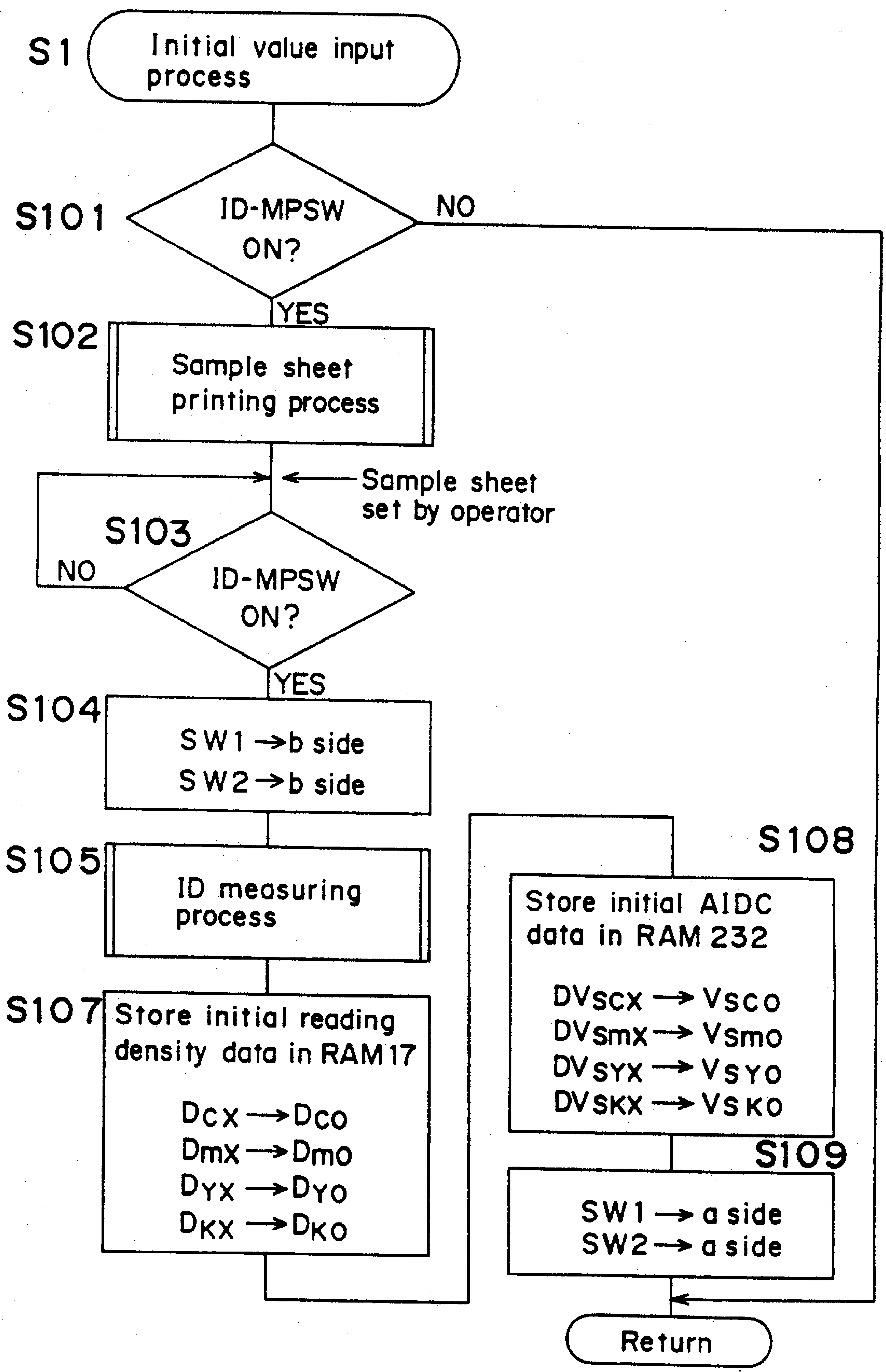

S1
Initial value input process
S101
ID-MPSW ON?
NO
YES
S102
Sample sheet printing process
Sample sheet set by operator
S103
NO
ID-MPSW ON?
YES
S104
SW1 → b side
SW2 → b side
S105
ID measuring process
S107
Store initial reading density data in RAM 17
Dcx → Dco
Dmx → Dmo
DYX → DYO
DKX → DKO
S108
Store initial AIDC data in RAM 232
DVscx → Vsco
DVsmx → Vsmo
DVsYX → VsYO
DVsKX → VsKO
S109
SW1 → a side
SW2 → a side
Return

Fig. 12

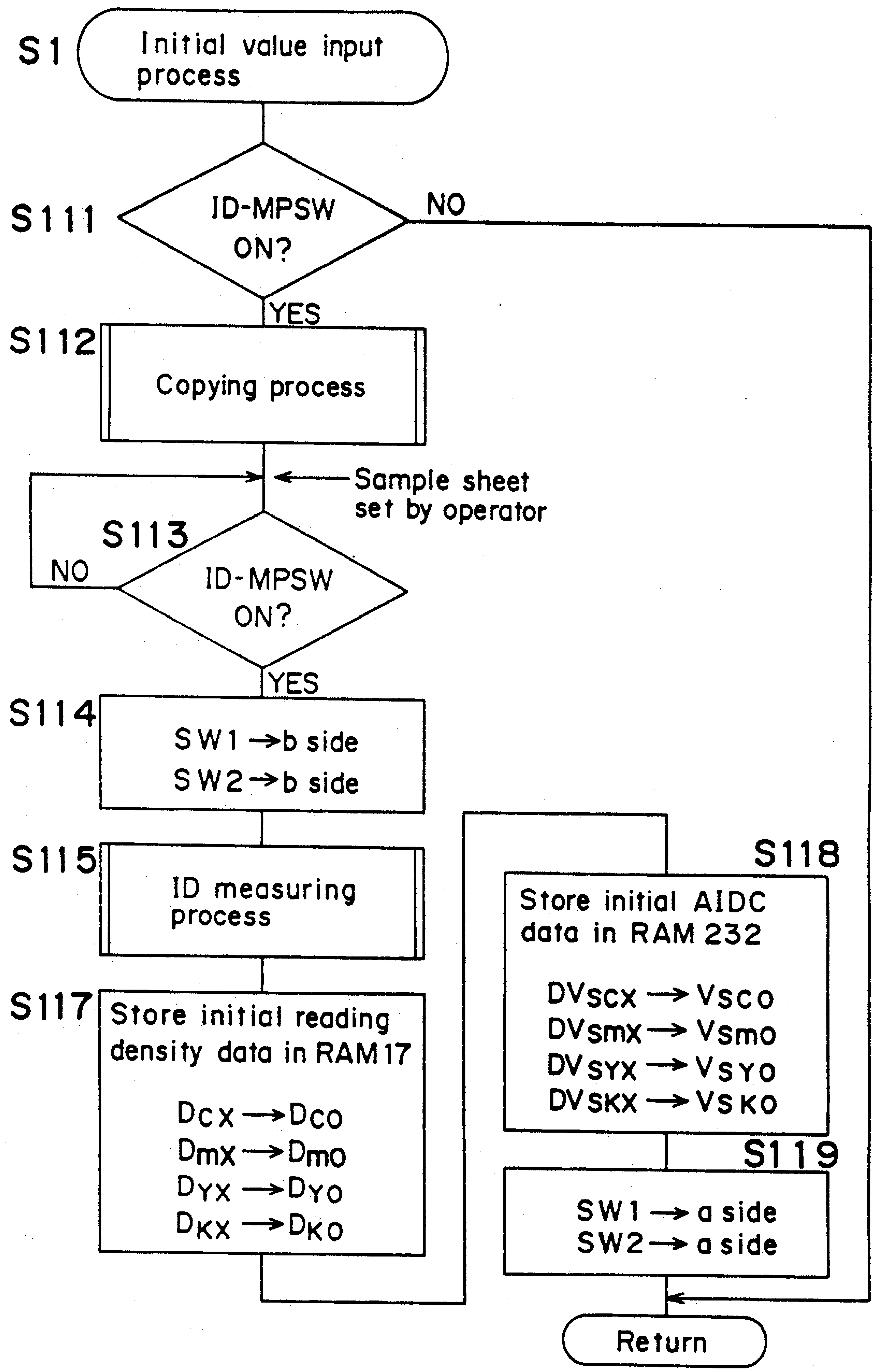

S1
Initial value input process
S111
ID-MPSW ON?
NO
YES
S112
Copying process
Sample sheet set by operator
S113
NO
ID-MPSW ON?
YES
S114
SW1 → b side
SW2 → b side
S115
ID measuring process
S117
Store initial reading density data in RAM 17
Dcx → Dco
Dmx → Dmo
DYX → DYO
DKX → DKO
S118
Store initial AIDC data in RAM 232
DVscx → Vsco
DVsmx → Vsmo
DVsYX → VsYO
DVsKX → VsKO
S119
SW1 → a side
SW2 → a side
Return

Fig. 13a

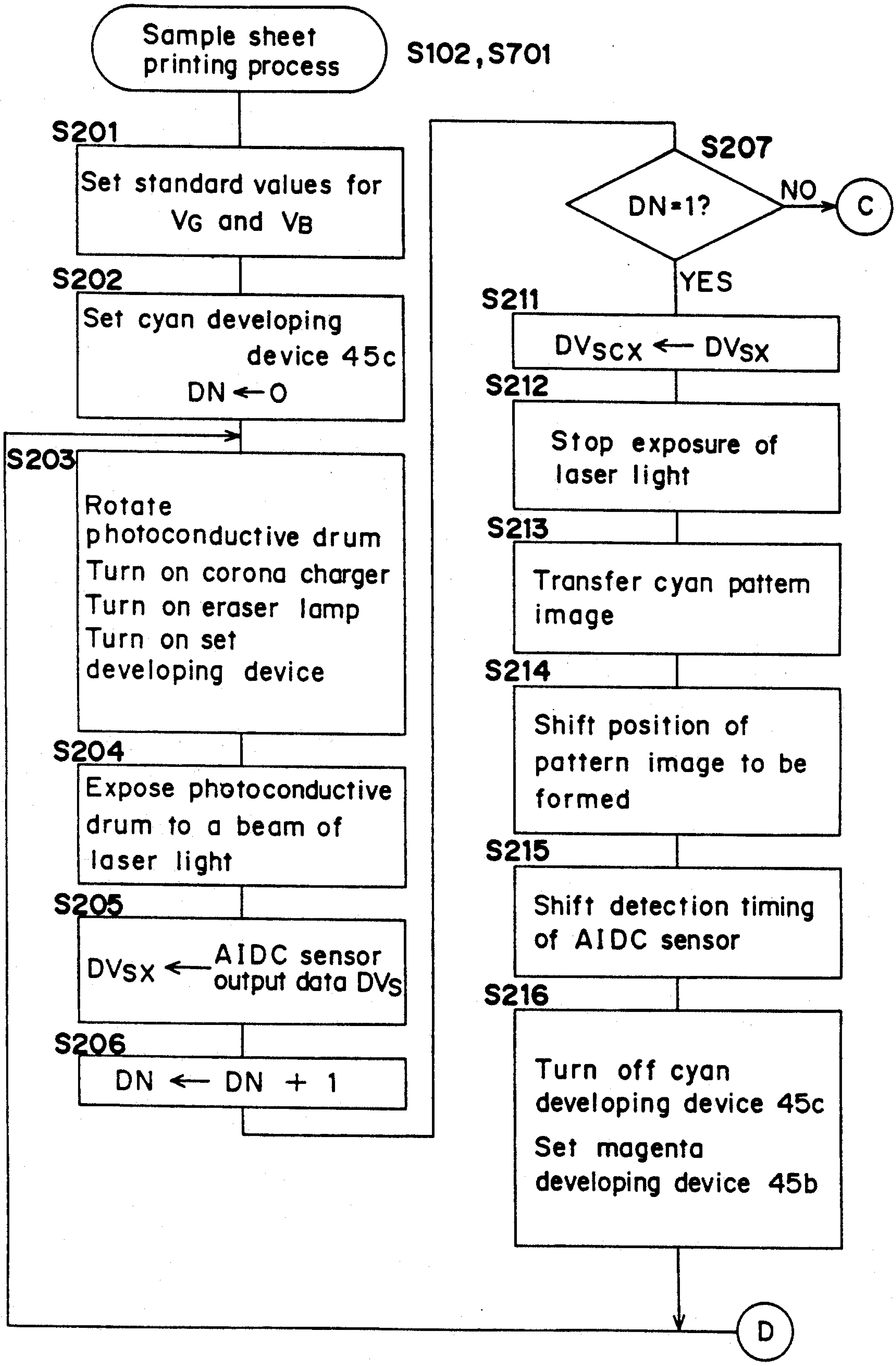

Sample sheet printing process
S102, S701
S201
Set standard values for VG and VB
S202
Set cyan developing device 45c
DN ← 0
S203
Rotate photoconductive drum
Turn on corona charger
Turn on eraser lamp
Turn on set developing device
S204
Expose photoconductive drum to a beam of laser light
S205
DVsx ← AIDC sensor output data DVs
S206
DN ← DN + 1
S207
DN=1?
NO
C
YES
S211
DVscx ← DVsx
S212
Stop exposure of laser light
S213
Transfer cyan pattern image
S214
Shift position of pattern image to be formed
S215
Shift detection timing of AIDC sensor
S216
Turn off cyan developing device 45c
Set magenta developing device 45b
D

Fig.13b

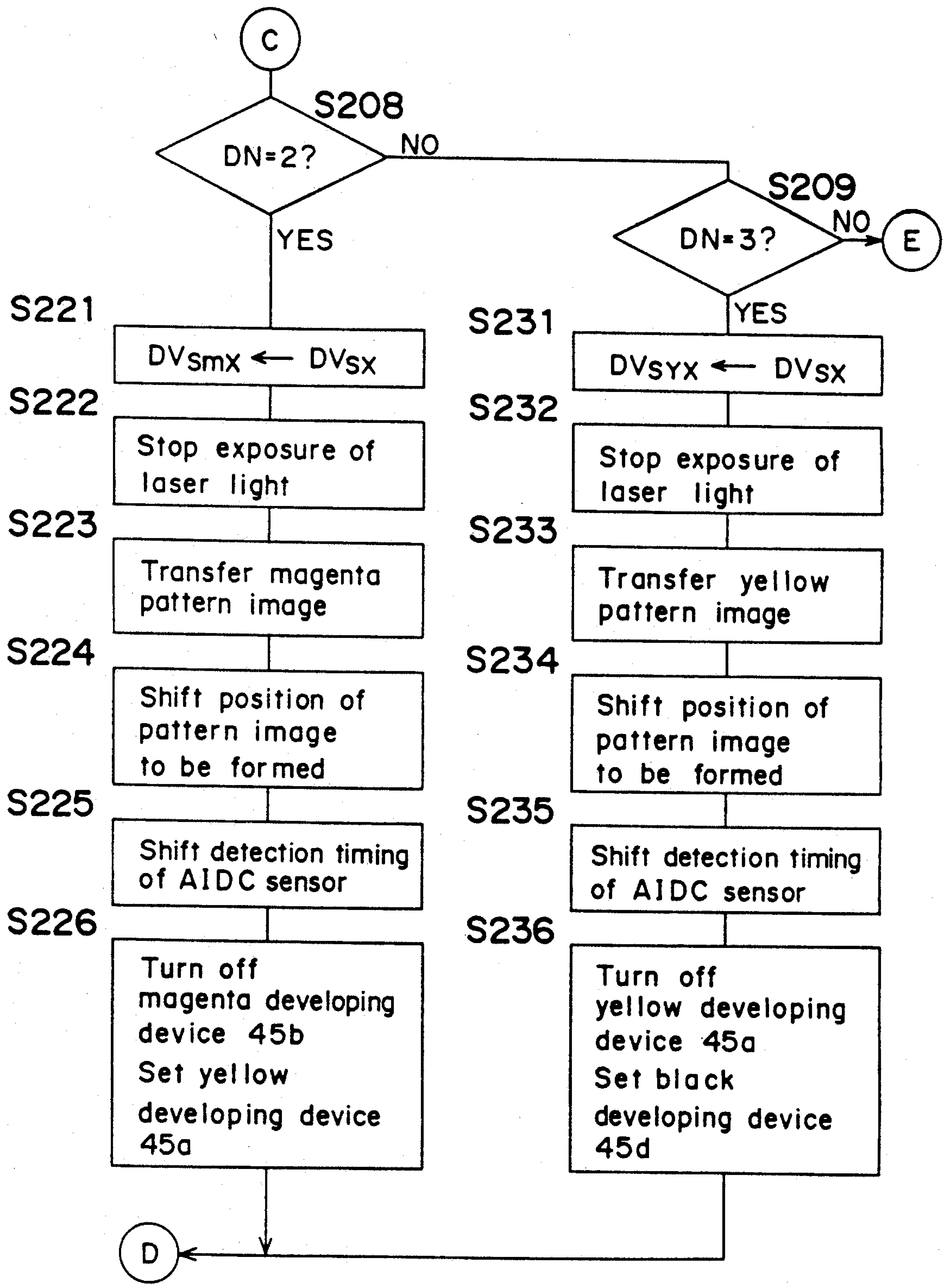

C
S208
DN=2?
NO
YES
S209
DN=3?
NO
E
YES
S221
DVsmx ← DVsx
S222
Stop exposure of laser light
S223
Transfer magenta pattern image
S224
Shift position of pattern image to be formed
S225
Shift detection timing of AIDC sensor
S226
Turn off magenta developing device 45b
Set yellow developing device 45a
S231
DVsyx ← DVsx
S232
Stop exposure of laser light
S233
Transfer yellow pattern image
S234
Shift position of pattern image to be formed
S235
Shift detection timing of AIDC sensor
S236
Turn off yellow developing device 45a
Set black developing device 45d
D

Fig. 13c

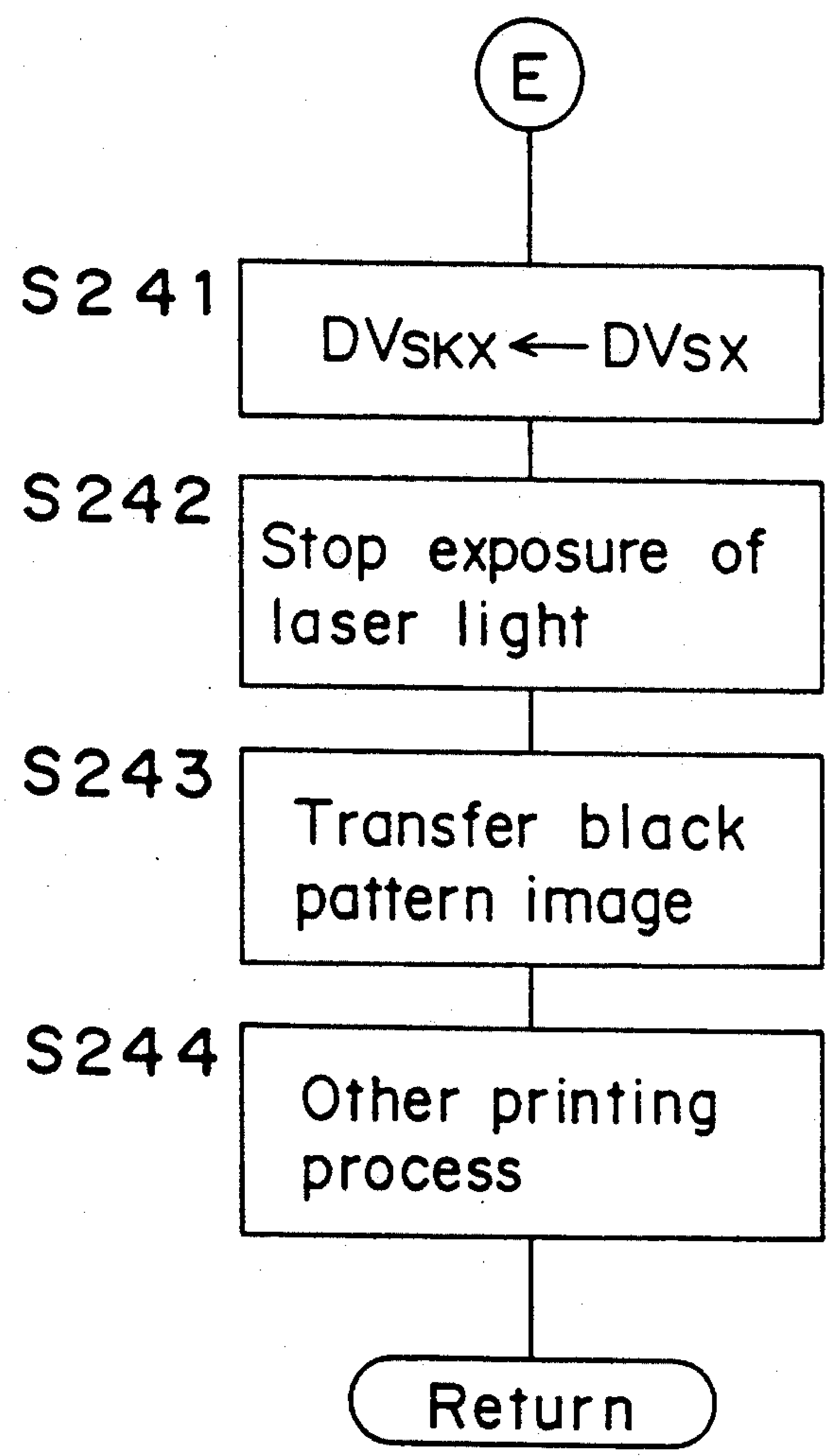

E
S241
DVSKX ← DVSX
S242
Stop exposure of laser light
S243
Transfer black pattern image
S244
Other printing process
Return

Fig. 14

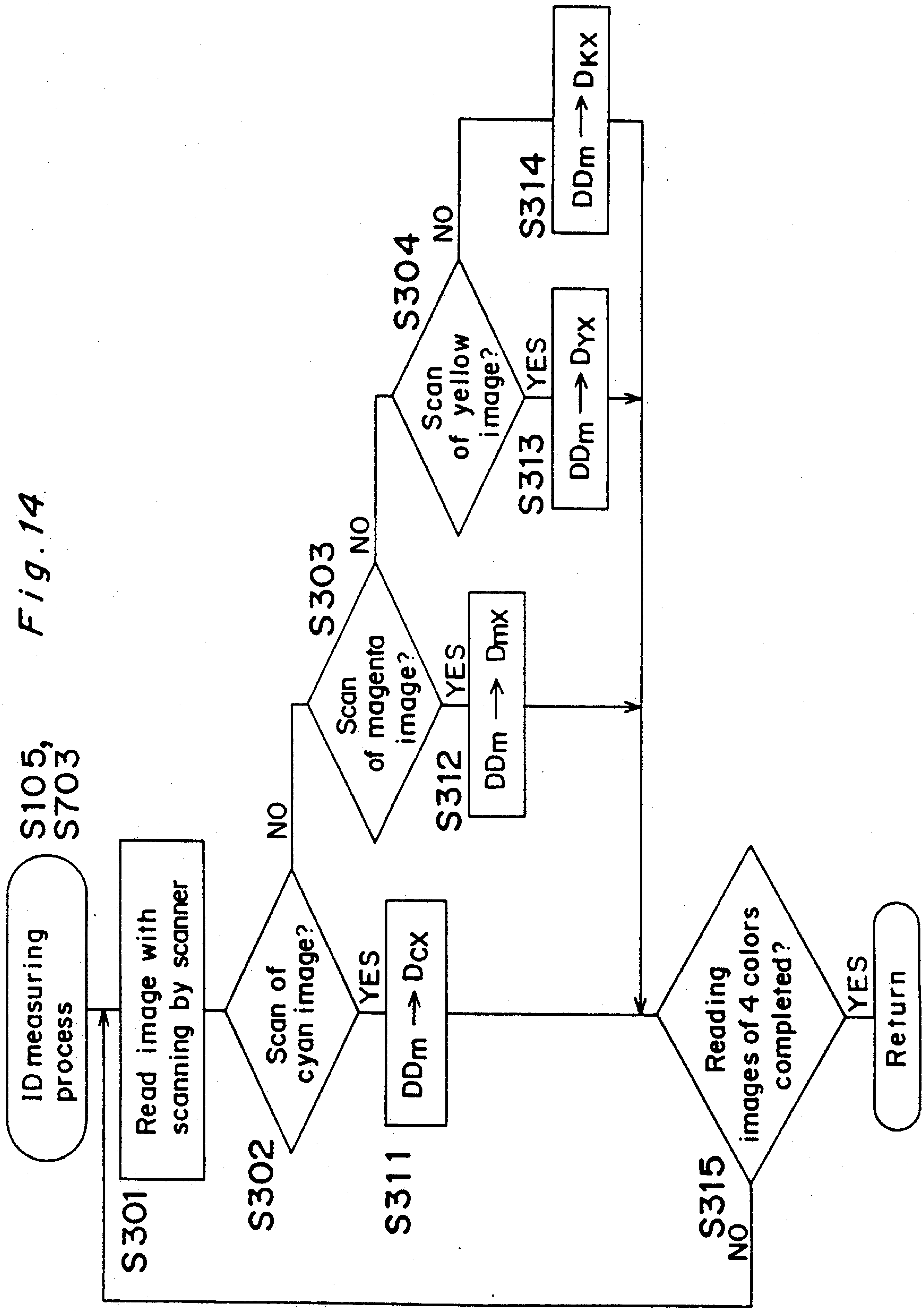

S105, S703
ID measuring process
S301
Read image with scanning by scanner
S302
Scan of cyan image?
YES
NO
S311
DDm → Dcx
S303
Scan of magenta image?
YES
NO
S312
DDm → Dmx
S304
Scan of yellow image?
YES
NO
S313
DDm → Dyx
S314
DDm → Dkx
S315
Reading images of 4 colors completed?
YES
NO
Return

Fig. 15a

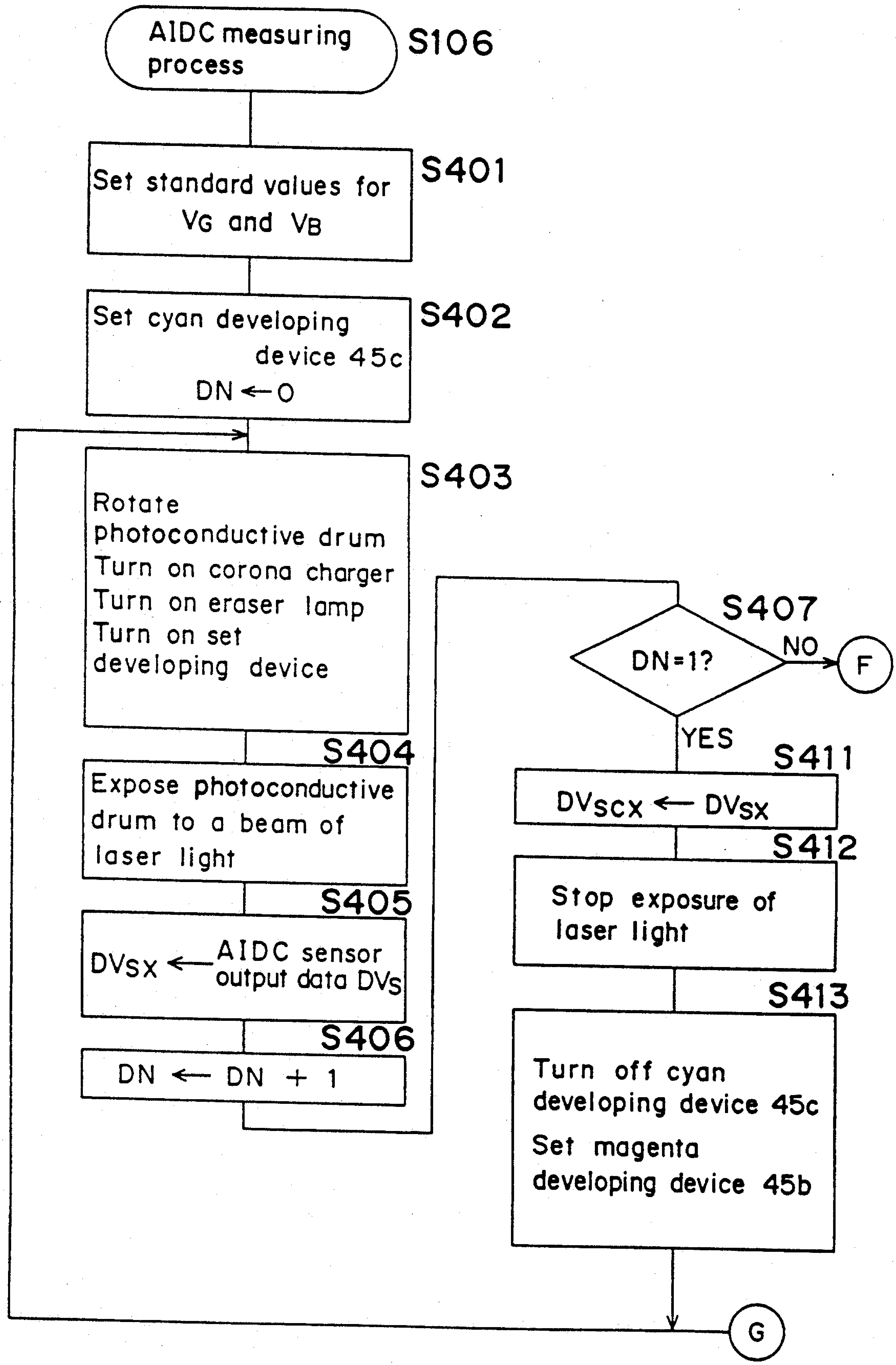
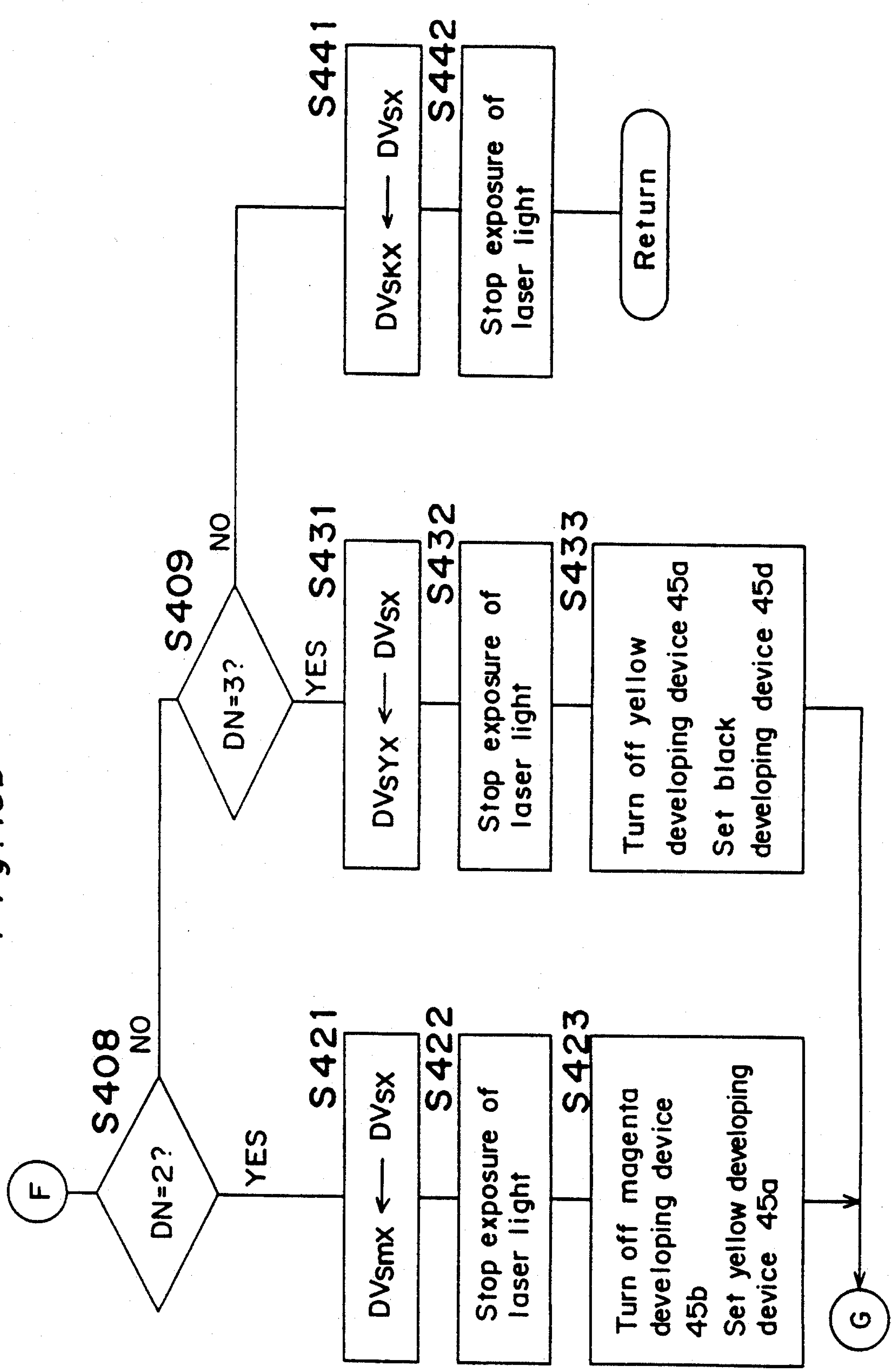

AIDC measuring process
S106
Set standard values for VG and VB
S401
Set cyan developing device 45c
DN ← 0
S402
Rotate photoconductive drum
Turn on corona charger
Turn on eraser lamp
Turn on set developing device
S403
Expose photoconductive drum to a beam of laser light
S404
DVsx ← AIDC sensor output data DVs
S405
DN ← DN + 1
S406
DN=1?
S407
NO
F
YES
DVscx ← DVsx
S411
Stop exposure of laser light
S412
Turn off cyan developing device 45c
Set magenta developing device 45b
S413
G

Fig. 15b


F
S408
DN=2?
YES
NO
S409
DN=3?
YES
NO
S421
DVsmX ⟵ DVsx
S422
Stop exposure of laser light
S423
Turn off magenta developing device 45b
Set yellow developing device 45a
S431
DVsYX ⟵ DVsx
S432
Stop exposure of laser light
S433
Turn off yellow developing device 45a
Set black developing device 45d
S441
DVsKX ⟵ DVsx
S442
Stop exposure of laser light
Return
G

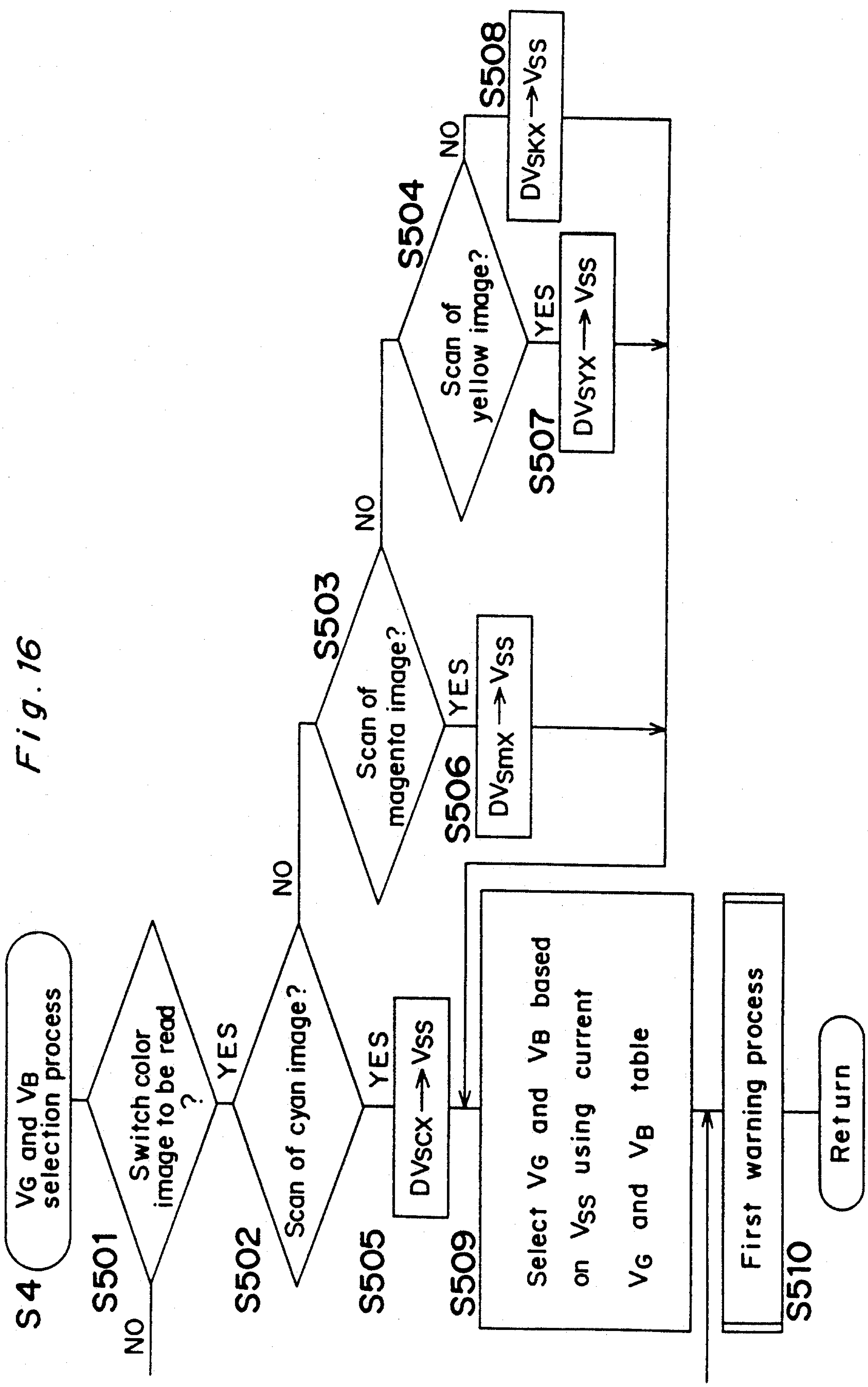

S4
V_G and V_B selection process
S501
Switch color image to be read ?
YES
NO
S502
Scan of cyan image?
YES
NO
S503
Scan of magenta image?
YES
NO
S504
Scan of yellow image?
YES
NO
S505
$DV_{SCX} \rightarrow V_{SS}$
S506
$DV_{SMX} \rightarrow V_{SS}$
S507
$DV_{SYX} \rightarrow V_{SS}$
S508
$DV_{SKX} \rightarrow V_{SS}$
S509
Select V_G and V_B based on V_{SS} using current V_G and V_B table
S510
First warning process
Return

Fig. 16

Fig. 17

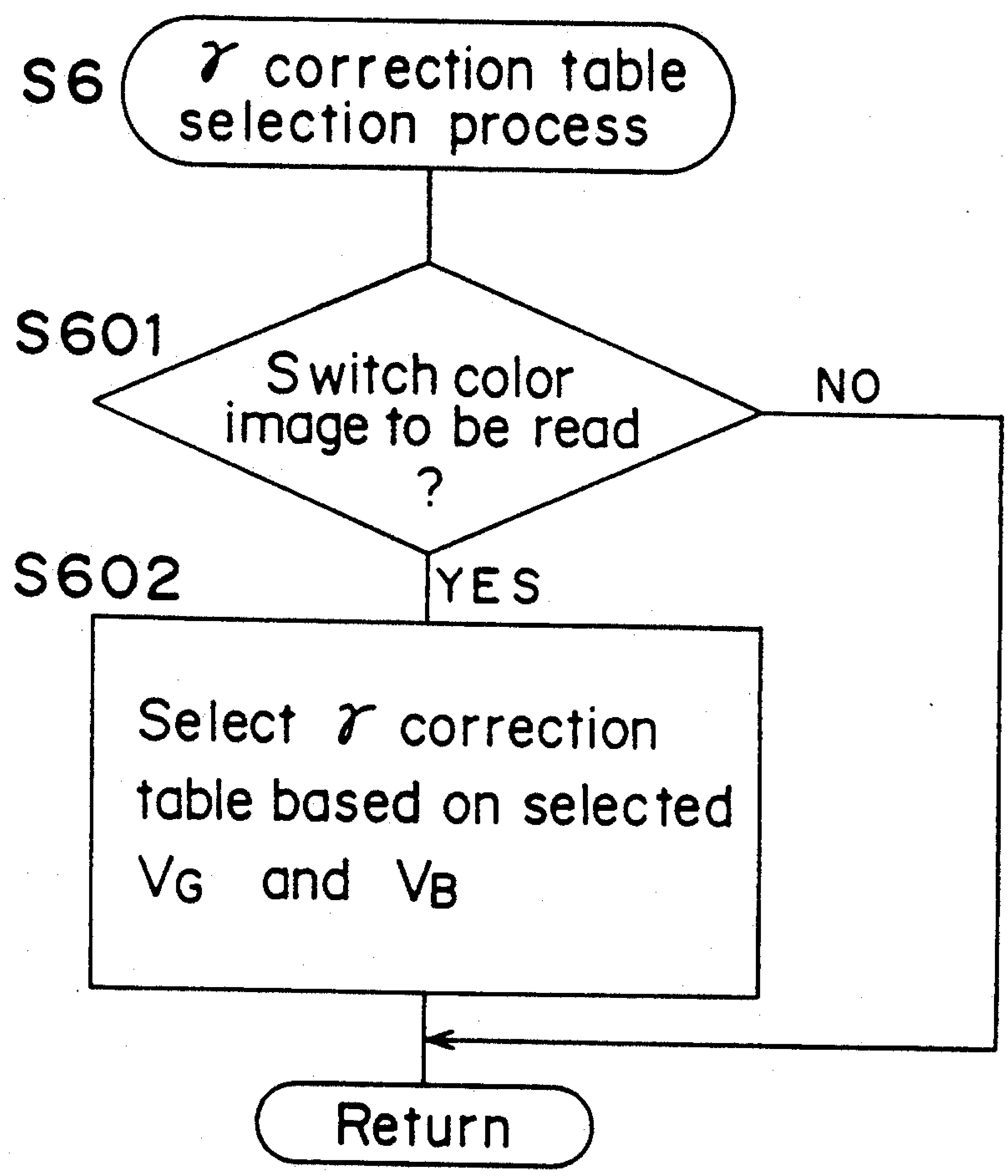

S6
γ correction table selection process
S601
Switch color image to be read ?
NO
S602
YES
Select γ correction table based on selected V_G and V_B
Return

Fig. 18

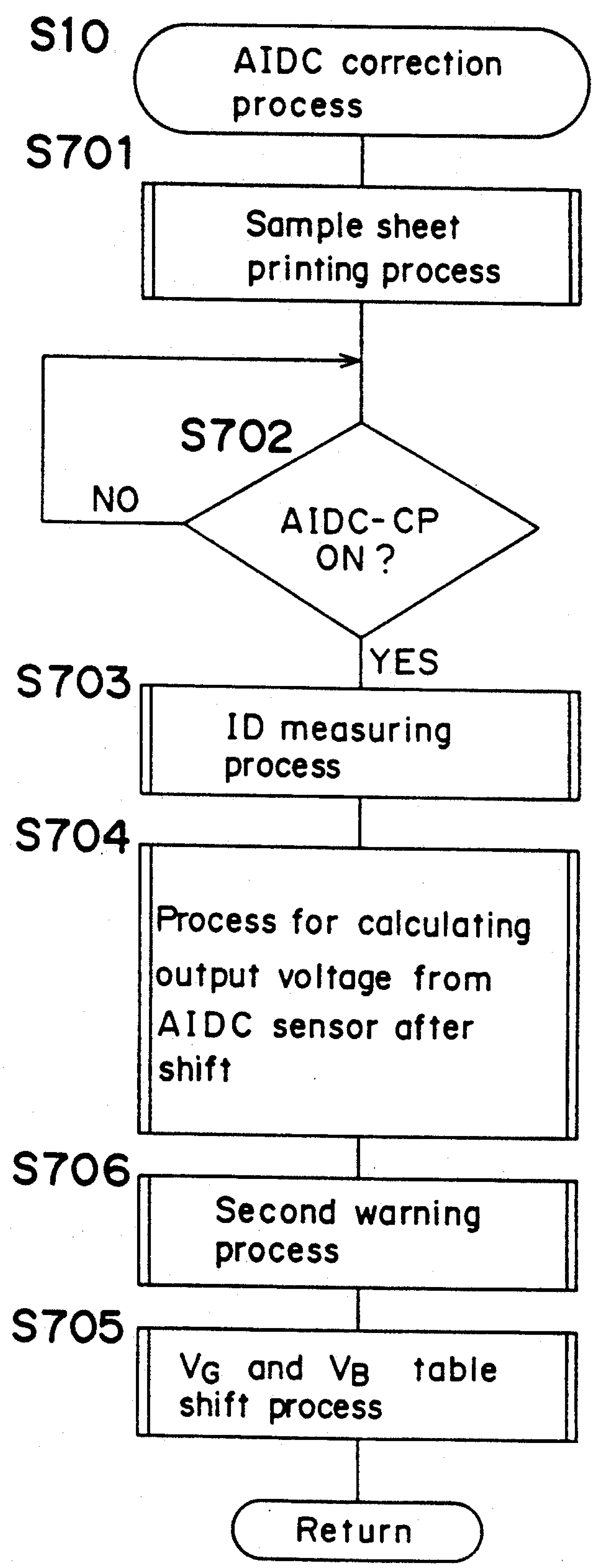

S10
AIDC correction process
S701
Sample sheet printing process
S702
AIDC-CP ON ?
NO
YES
S703
ID measuring process
S704
Process for calculating output voltage from AIDC sensor after shift
S706
Second warning process
S705
V_G and V_B table shift process
Return

Fig. 19a

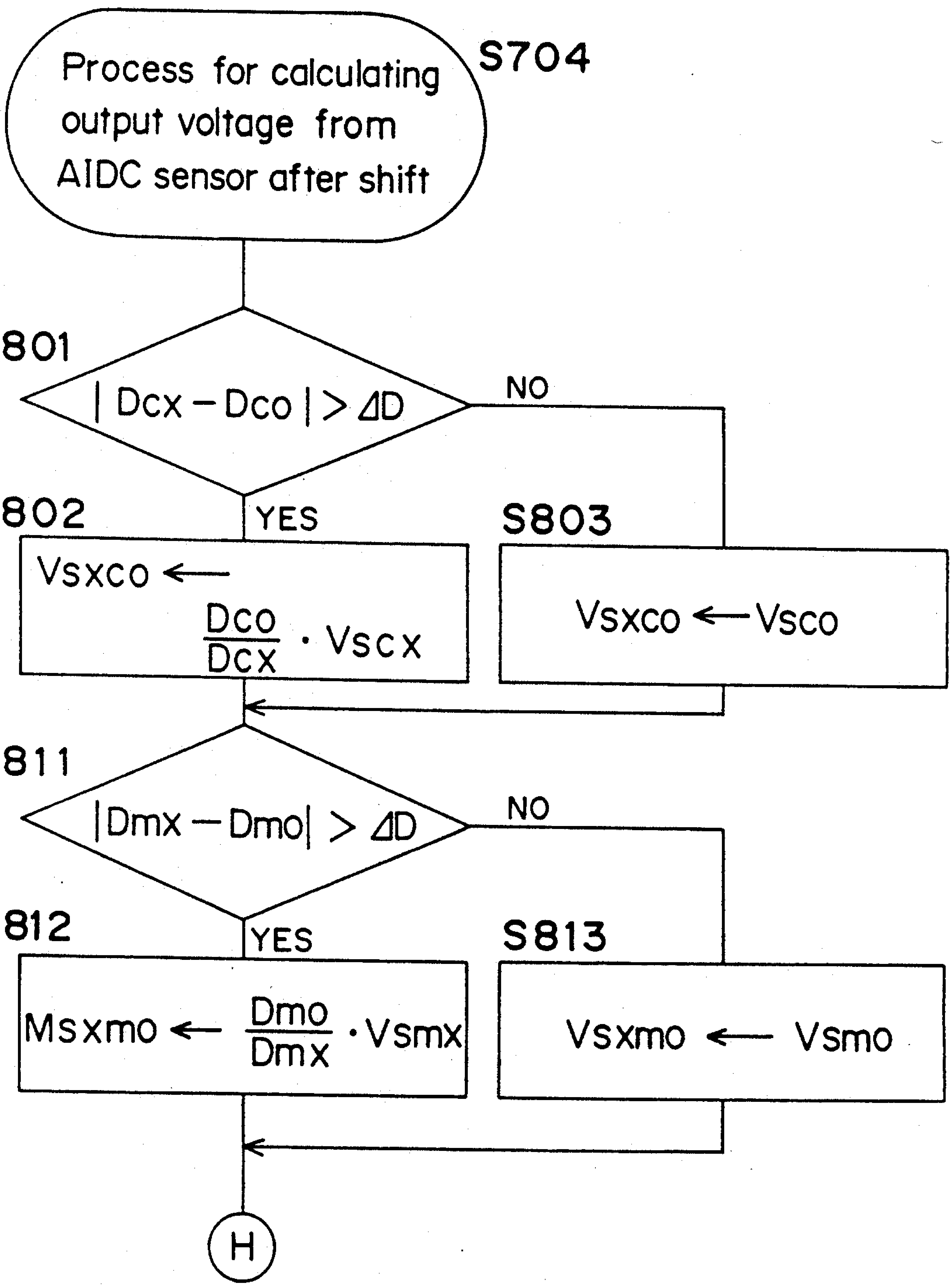

Process for calculating output voltage from AIDC sensor after shift
S704
S801
| Dcx − Dco | > ΔD
NO
YES
S802
Vsxco ← Dco/Dcx · Vscx
S803
Vsxco ← Vsco
S811
|Dmx − Dmo| > ΔD
NO
YES
S812
Msxmo ← Dmo/Dmx · Vsmx
S813
Vsxmo ← Vsmo
H

Fig. 19b

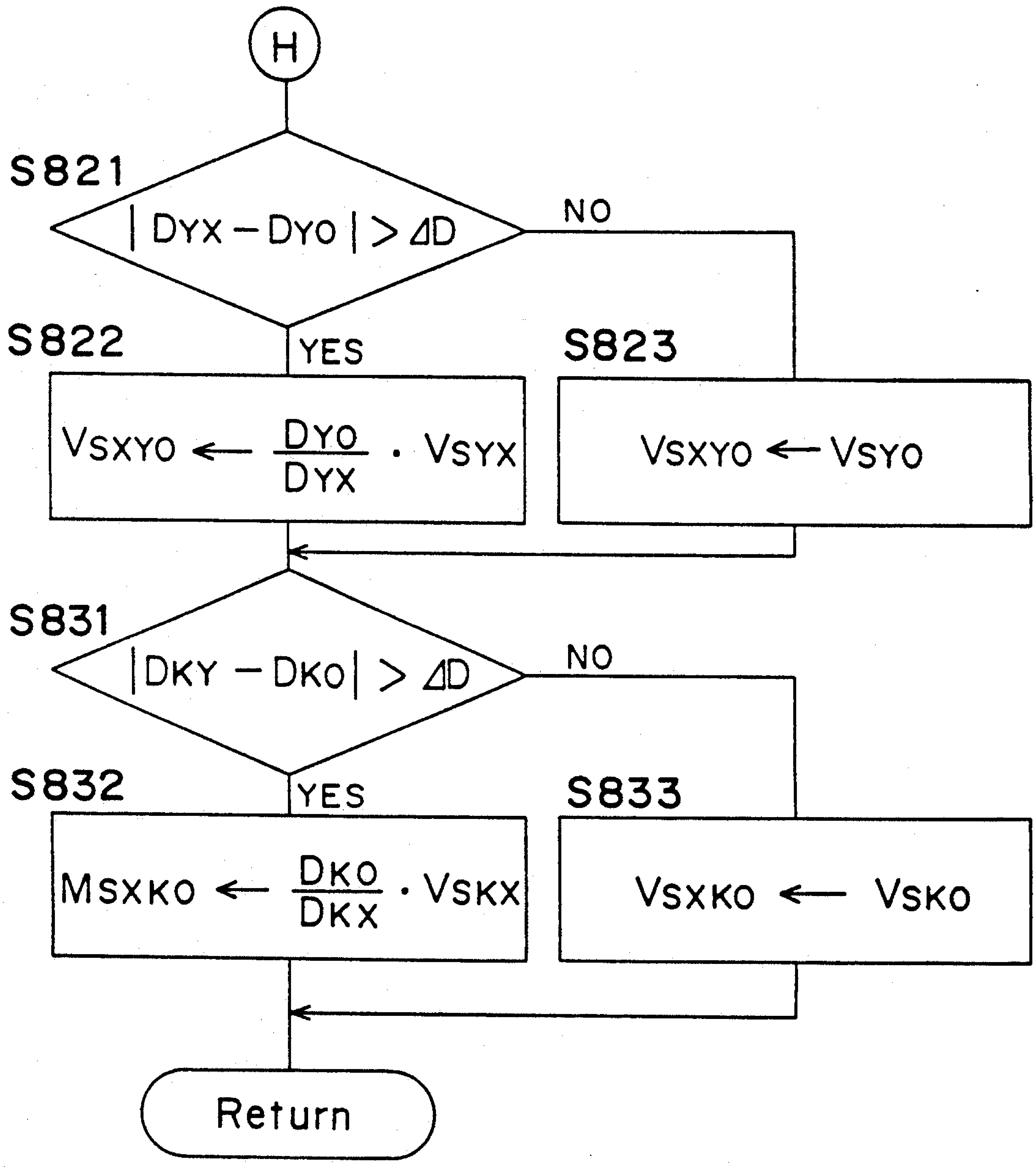

H
S821
| DYX − DYO | > ΔD
NO
YES
S822
VSXYO ← DYO/DYX · VSYX
S823
VSXYO ← VSYO
S831
|DKY − DKO| > ΔD
NO
YES
S832
MSXKO ← DKO/DKX · VSKX
S833
VSXKO ← VSKO
Return

Fig. 20

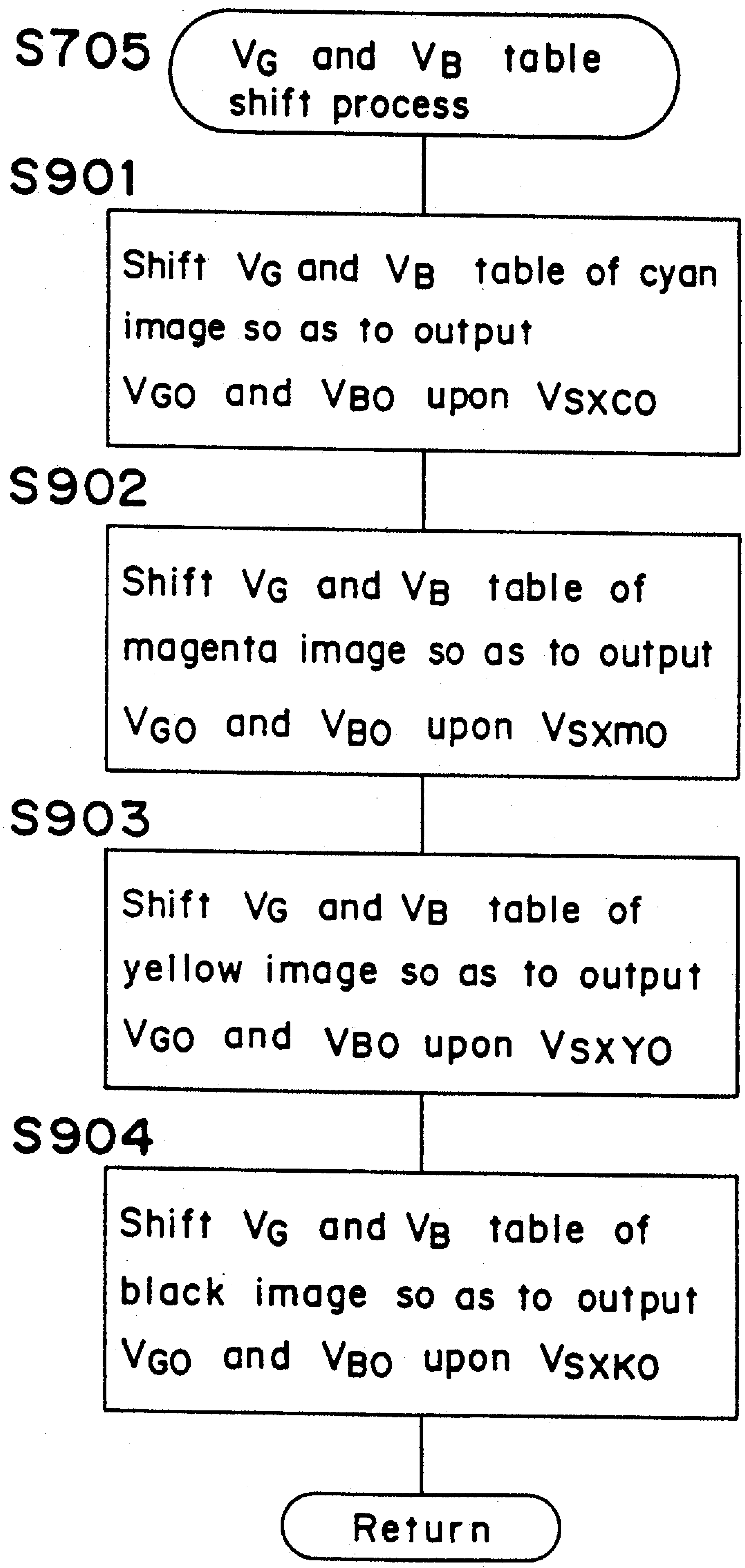

S705
V_G and V_B table shift process
S901
Shift V_G and V_B table of cyan image so as to output V_{GO} and V_{BO} upon V_{SXCO}
S902
Shift V_G and V_B table of magenta image so as to output V_{GO} and V_{BO} upon V_{SXmO}
S903
Shift V_G and V_B table of yellow image so as to output V_{GO} and V_{BO} upon V_{SXYO}
S904
Shift V_G and V_B table of black image so as to output V_{GO} and V_{BO} upon V_{SXKO}
Return

Fig. 21

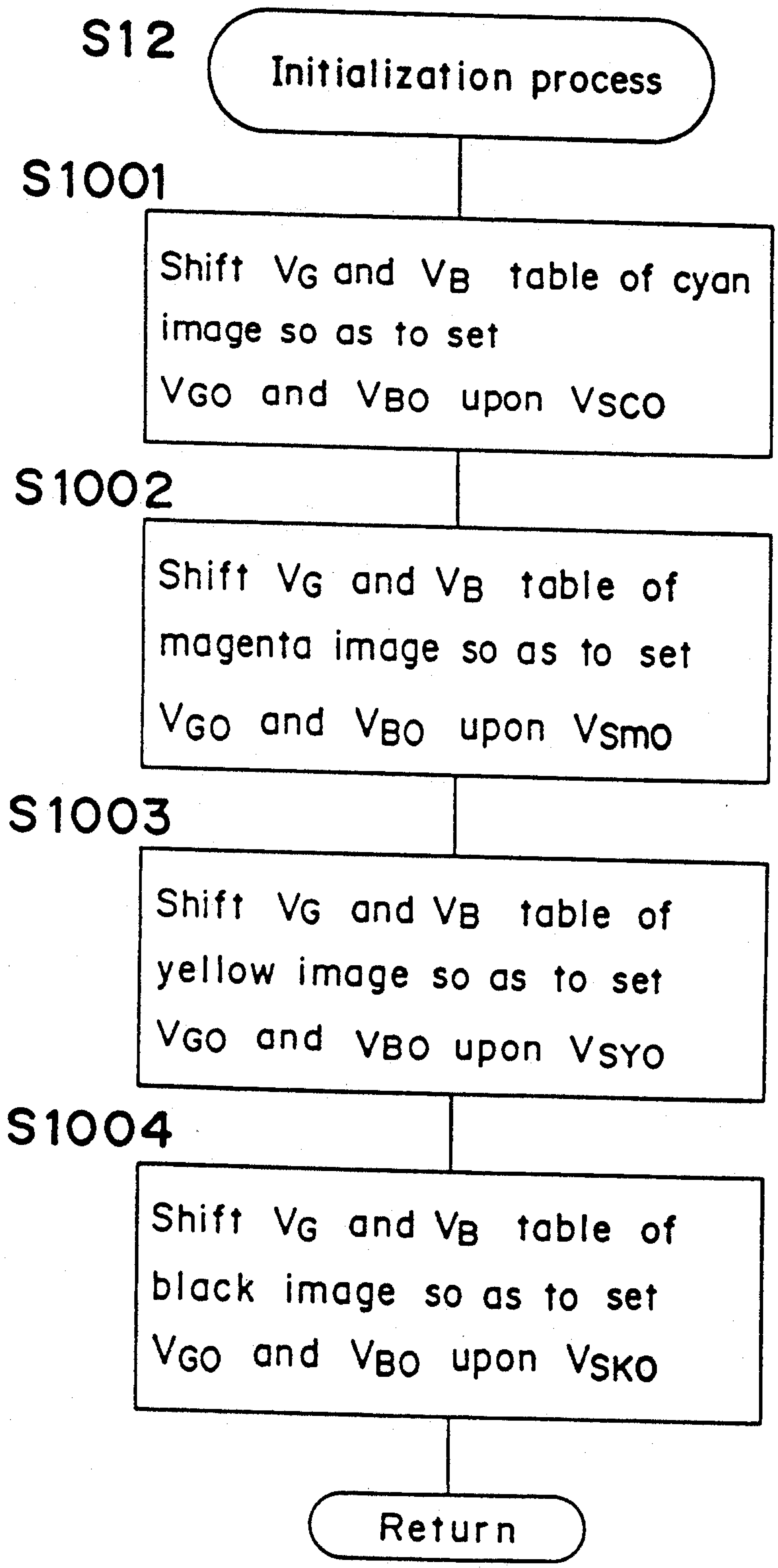

S12
Initialization process
S1001
Shift VG and VB table of cyan image so as to set VGO and VBO upon VSCO
S1002
Shift VG and VB table of magenta image so as to set VGO and VBO upon VSMO
S1003
Shift VG and VB table of yellow image so as to set VGO and VBO upon VSYO
S1004
Shift VG and VB table of black image so as to set VGO and VBO upon VSKO
Return

Fig. 22a

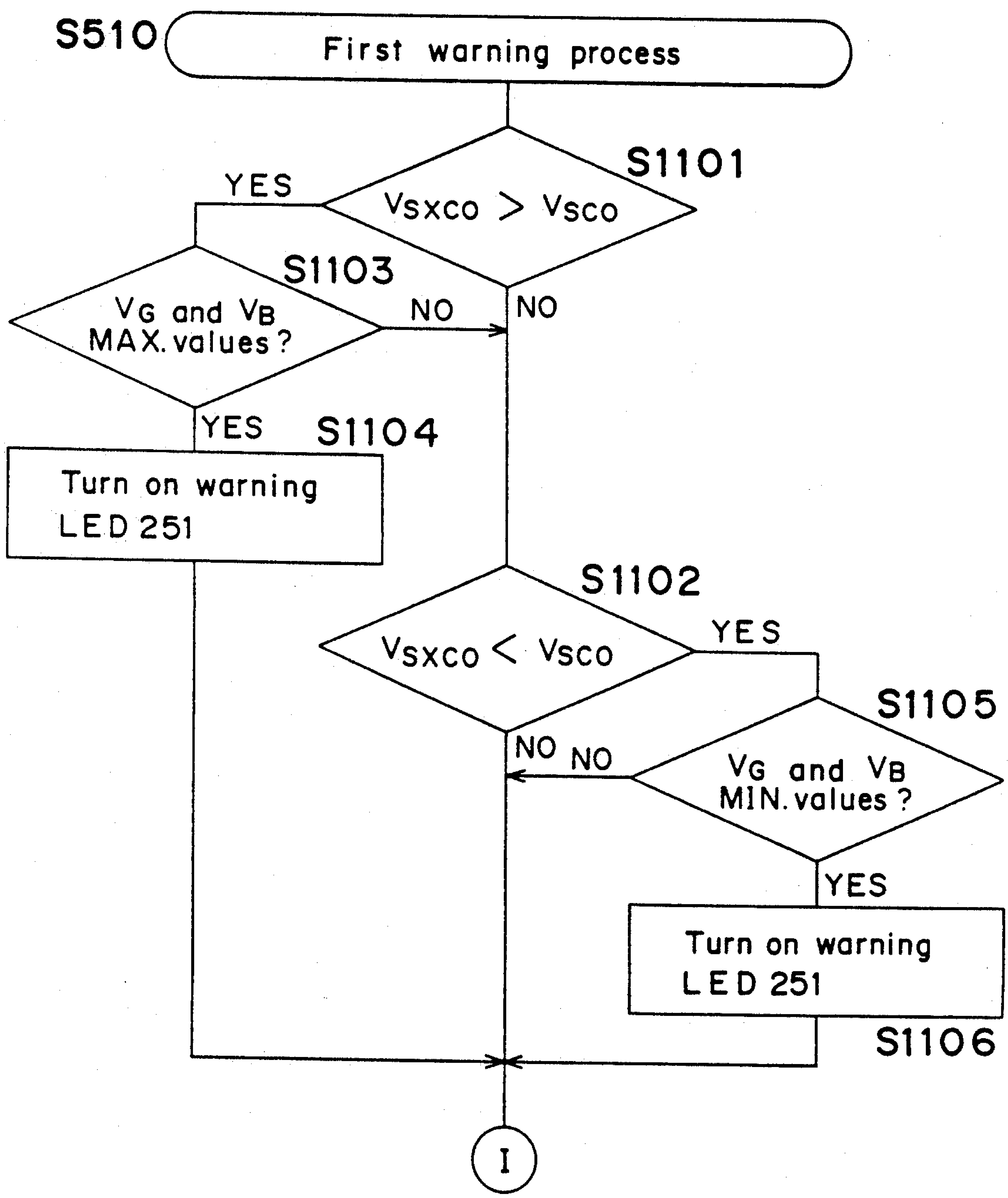

S510
First warning process
S1101
Vsxco > Vsco
YES
NO
S1103
VG and VB MAX. values ?
NO
YES
S1104
Turn on warning LED 251
S1102
Vsxco < Vsco
YES
NO
S1105
VG and VB MIN. values ?
NO
YES
Turn on warning LED 251
S1106
I

Fig. 22b

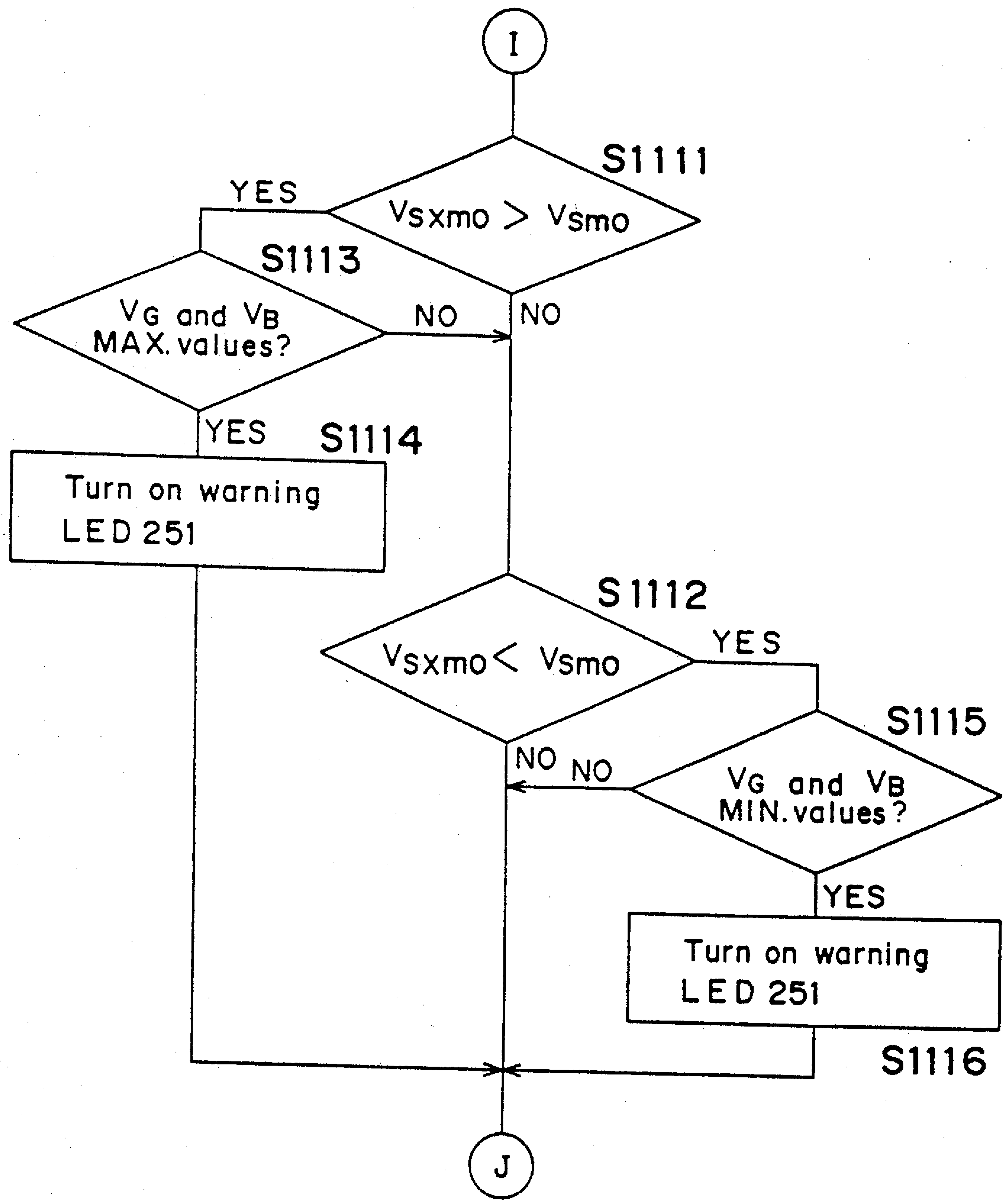

I
S1111
Vsxmo > Vsmo
YES
NO
S1113
VG and VB
MAX. values?
NO
YES
S1114
Turn on warning
LED 251
S1112
Vsxmo < Vsmo
YES
NO
S1115
VG and VB
MIN. values?
NO
YES
Turn on warning
LED 251
S1116
J

Fig.22c

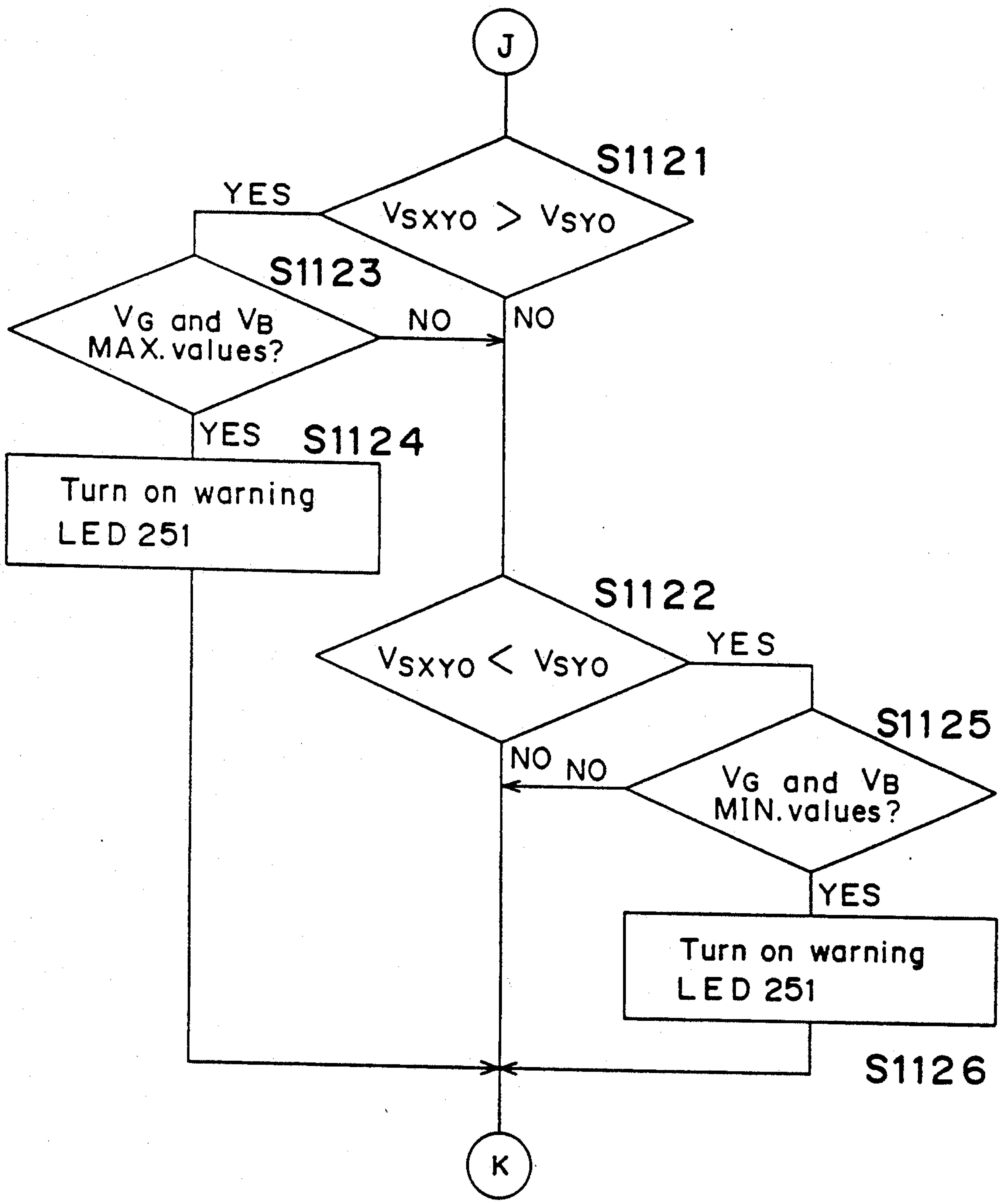

J
S1121
YES
VSXYO > VSYO
S1123
VG and VB
MAX. values?
NO
NO
YES
S1124
Turn on warning
LED 251
S1122
YES
VSXYO < VSYO
S1125
NO
NO
VG and VB
MIN. values?
YES
Turn on warning
LED 251
S1126
K

Fig.22d

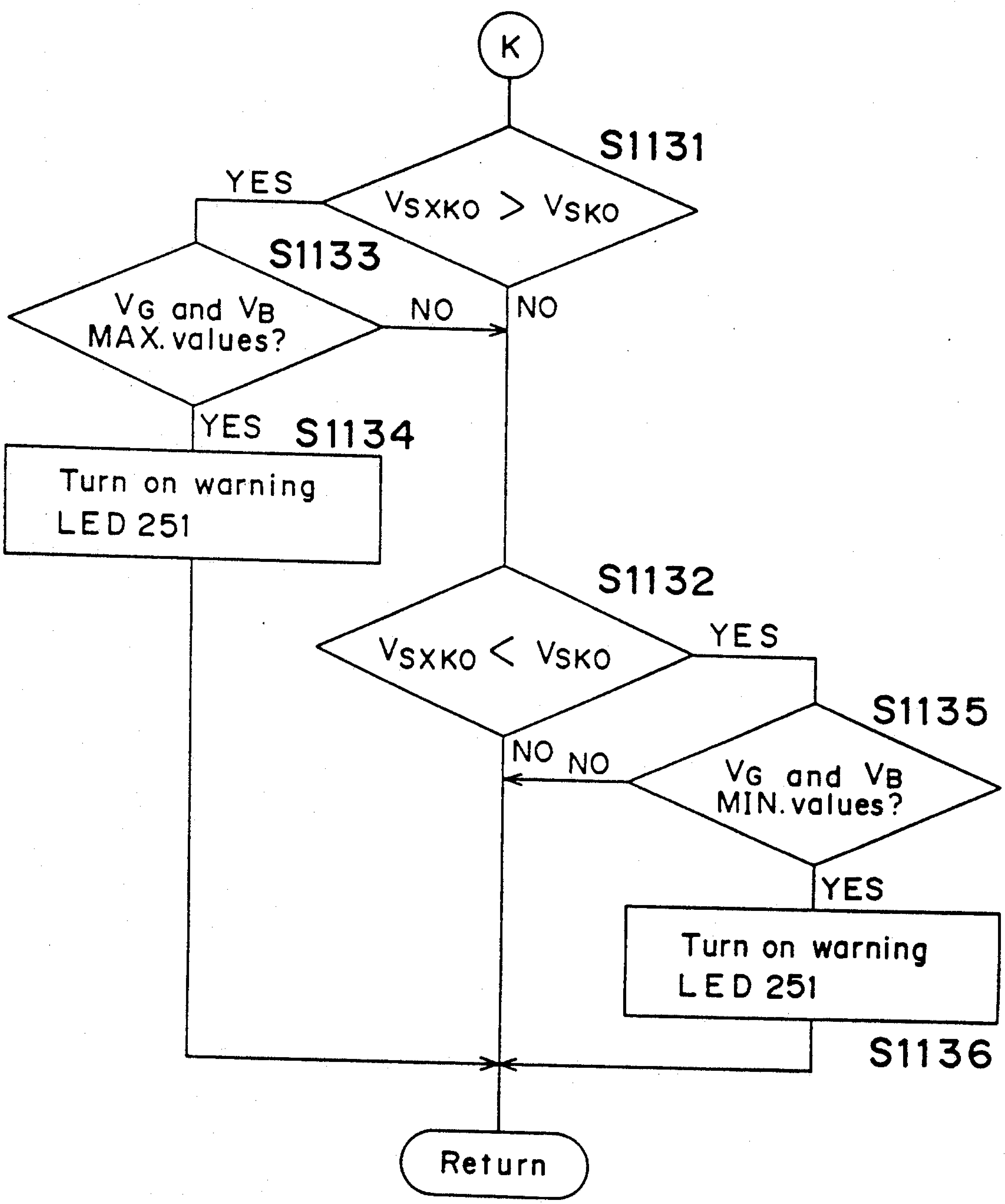

K
S1131
$V_{SXKO} > V_{SKO}$
YES
NO
S1133
V_G and V_B MAX. values?
NO
YES
S1134
Turn on warning LED 251
S1132
$V_{SXKO} < V_{SKO}$
YES
NO
S1135
V_G and V_B MIN. values?
NO
YES
Turn on warning LED 251
S1136
Return

Fig. 23

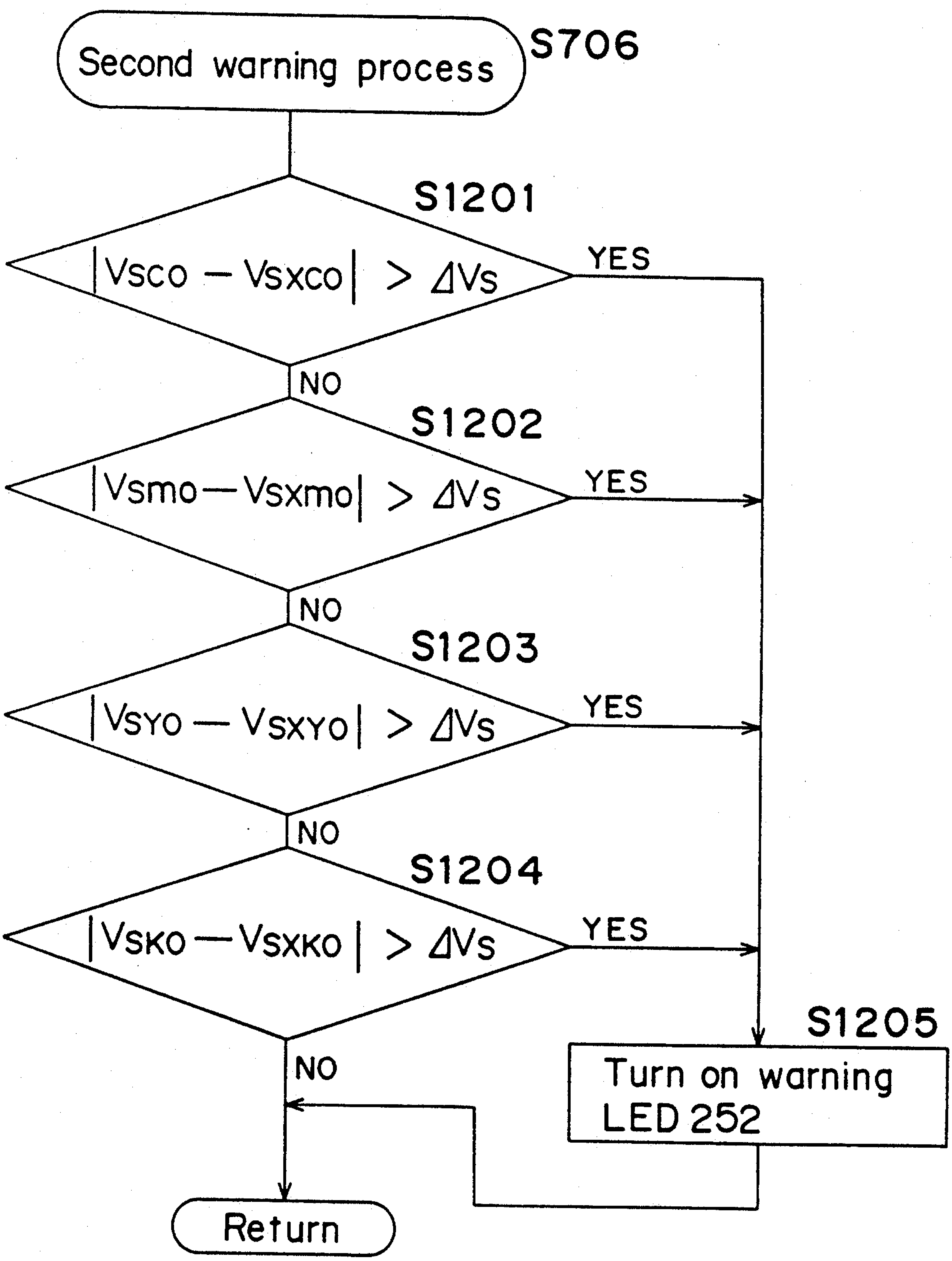

Second warning process
S706
S1201
|Vsco − Vsxco| > ΔVs
YES
NO
S1202
|Vsmo−Vsxmo| > ΔVs
YES
NO
S1203
|Vsyo − Vsxyo| > ΔVs
YES
NO
S1204
|Vsko−Vsxko| > ΔVs
YES
NO
S1205
Turn on warning LED 252
Return

IMAGE FORMING APPARATUS COMPRISING MEANS FOR AUTOMATICALLY ADJUSTING IMAGE DENSITY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an image forming apparatus, and more particularly, to an image forming apparatus using an electrophotographic process such as an image forming apparatus provided in a digital full color copying machine using an electrophotographic process, comprising means for automatically adjusting an image density of an image to be reproduced so as to obtain a desirable proper image density thereof.

2. Description of the Related Art

Conventionally, there have been put into practical use various kinds of electrophotographic image forming apparatuses such as a laser printer for driving a laser diode based on digital image data of an image of an original and reproducing the image of the original on a sheet of printing paper. Further, there have been proposed various kinds of digital image forming methods for faithfully reproducing a half-tone image such as a photograph.

As the digital image forming methods of these type, there have been known to those skilled in the art, an area gradation method using a dither matrix, and multi-value laser exposure methods such as a pulse width modulation method for representing a gradation of one dot image to be printed by changing a pulse width or an emitting time of a beam of laser light so as to change a light amount thereof defined as a product of the emitting time and an emitting intensity, and an intensity modulation method for representing a gradation of one dot image to be printed by changing an emitting intensity of a beam of laser light so as to change a light amount thereof (See Japanese Patent Laid-open Publication Nos. 62-91077, 62-39972, 62-188562 and 61-22597). Further, there has been publicly known a multi-value dither method which is a combination of the dither method and the above-mentioned pulse width modulation method or the above-mentioned intensity modulation method.

In the gradation method of this type for representing a gradation, it is considered possible in principle to reproduce an image density having a gradation strictly corresponding to a gradation of image data to be reproduced, however, an original density to be reproduced is not correctly proportional to an actually reproduced image density (referred to as an image density hereinafter) because of a complicated combination of characteristics of a photoconductor and toners and circumstances etc. In other words, a relationship between the image density and the original density shows a characteristic curve B which is shifted from a characteristic curve A to be originally obtained, as schematically shown in FIG. 4. Such characteristic as above is generally called a γ characteristic, which mainly causes deterioration of faithfulness of reproduced images of originals, particularly of a half-tone original.

Therefore, in order to improve faithfulness of a reproduced image, conventionally, there has been performed a so-called γ correction process for converting data of a read original density into data using a predetermined γ correction table and forming a digital image of dot images based on the converted data of the original density so that the relationship between the original density and the image density becomes linear, namely, the above-mentioned linear characteristic A shown in FIG. 4 can be obtained. Thus, normally, the image of the original can be faithfully reproduced depending on the original density by performing the above-mentioned the γ correction process.

On the other hand, as one of phenomena due to another cause for influencing the image density, there is such a phenomenon that an adhering amount of toner onto the photoconductor changes upon a developing process using the toner when characteristics of the photoconductor and the toner changes due to change in external circumstances such as the temperature, the humidity, etc. Generally speaking, the adhering amount of toner increases under circumstances of a high temperature and a high humidity so that the original image having a higher image density is reproduced with a γ characteristic having a relatively large gradient in a relatively high original density. On the other hand, the adhering amount of toner decreases under circumstances of a low temperature and a low humidity so that the original image having a lower image density is reproduced with a γ characteristic having a relatively small gradient in relatively low and middle original densities.

Thus, there is such a problem that the reproduced image density changes due to change in the circumstances. In order to solve the above-mentioned problem so as to obtain a stable proper image density, there has been performed an image density control process for controlling the maximum image density to be constant, generally, in a conventional electrophotographic copying machine, a conventional electrophotographic printer, or the like.

One of the above-mentioned image density control processes which has been put into practical use will be described below with reference to FIG. 5 for illustrating an image forming part comprising a photoconductive drum **41** and a developing roller **45r**.

Referring to FIG. 5, a corona charger **43** having a discharging electric potential V_C is provided so as to confront a photoconductive drum **41**. A grid voltage V_G is applied to a grid of the corona charger **43** by a grid voltage V_G generator **214**. An electric potential Vo on the surface of the photoconductive drum **41** is controlled by changing the grid voltage V_C based on the electric potential Vo detected by a Vo sensor **44**.

In the first place, prior to an exposure of a beam of laser light, a negative surface electric potential Vo is applied to the photoconductive drum **41** by the corona charger **43**, and a negative developing bias voltage V_B ($|Vo|>|V_B|$) of a relatively low electric potential is applied to the developing roller **45r** by a developing bias voltage V_B generator **215** in order to prevent a fog. In this case, the surface electric potential of a developing sleeve of the developing device is also set to the developing bias voltage V_B.

The surface electric potential Vo of the photoconductive drum **41** changes upon an exposure of a beam of laser light (referred to as a light exposure hereinafter) into an electrostatic latent image electric potential V_I upon the light exposure with the maximum light amount of the laser light. When the electrostatic latent image electric potential V_L becomes lower than the developing bias voltage V_B, the toner adheres onto the photoconductive drum **41**. The adhering amount of toner increases as a difference between the developing bias voltage V_B and electrostatic latent image electric potential V_L becomes larger. Therefore, since the difference between the developing bias voltage V_B and electrostatic latent image electric potential V_L is changed by changing the surface electric potential Vo on the photoconductive drum **41** and the developing bias voltage V_B, the adhering amount of toner onto the photoconductive drum **41** can be changed, thereby eventually controlling the image density of the toner image.

According to the image density control process of this type as described above, the maximum image density is made constant by automatically or manually by an operator's changing the surface electric potential Vo on the photoconductive drum **41** and/or the developing bias voltage V_B.

In the automatic image density control process, a reference toner image of a reference image pattern which becomes a reference for the image density control process is formed on the surface of the photoconductive drum **41**, and a light amount of a reflected light from the reference toner image is detected by an automatic image density controlling sensor (referred to as an AIDC sensor hereinafter) **203** provided in the vicinity of the photoconductive drum **41**. Data of the detection value detected by the AIDC sensor **203** are inputted to a printer controller **201**, which in turn controls the grid voltage V_G generator **214** and the developing bias voltage V_B generator **215** in accordance with a comparison result between the data of the detection value detected by the AIDC sensor **203** and a predetermined value. The above-mentioned process is repeated until the adhering amount of toner becomes the predetermined value.

However, even through the image density control process is performed so as to make the image density constant on the basis of the output of the AIDC sensor **203**, a relationship between the output of the AIDC sensor **203** and the actual image density of the reference toner image changes due to change in characteristics of the AIDC sensor **203** and the circumstances from those in the initial state when the digital full color copying machine is manufactured. Therefore, the automatic image density control process can not be stably performed.

SUMMARY OF THE INVENTION

The object of the present invention is therefore to provide an image forming apparatus using an electrophotographic process, capable of automatically adjusting an image density of an image to be produced so as to reproducing the image having a proper image density even though a relationship between the output of the AIDC sensor **203** and the image density changes from that in an initial state when shipping the image forming apparatus from the factory for manufacturing it.

In order to achieve the aforementioned objective, according to the aspect of the present invention, there is provided an image forming apparatus for forming an image on a sheet of paper, comprising:

an image retaining member;

image forming means for forming a reference toner image having a predetermined density on said image retaining member;

first detection means for detecting a density of said reference toner image formed on said image retaining member and outputting first density data for representing the detected density thereof;

transfer means for transferring said reference toner image formed on said image retaining member onto a sheet of paper;

second detection means for detecting a density of said reference toner image transferred on said sheet of paper and outputting second density data for representing the detected density thereof; and

adjustment means for automatically adjusting an image density of an image formed on a sheet of paper so as to obtain a predetermined image density by controlling operation conditions of said image forming apparatus based on said first and second density data respectively outputted from said first and second detection means.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features of the present invention will become clear from the following description taken in conjunction with the preferred embodiments thereof with reference to the accompanying drawings throughout which like parts are designated by like reference numerals, and in which:

FIG. **1** is a longitudinal cross sectional view of a digital full color copying machine according to one embodiment of the present invention;

FIGS. **2***a*, **2***b* and **2***c* are block diagrams of the digital full color copying machine shown in FIG. **1**;

FIG. **3** is a block diagram of an image signal processing part, a print head controller and a print head part of the digital full color copying machine shown in FIGS. **1** and **2***a* to **2***c*;

FIG. **4** is a graph of an example of a γ characteristic;

FIG. **5** is a block diagram of respective units provided around a photoconductive drum of the digital full color copying machine shown in FIGS. **1** and **2***a* to **2***c*;

FIG. **6** is a plane view of a sample sheet used in the digital full color copying machine of FIGS. **1** and **2***a* to **2***c*, and a timing chart of output signals of a CCD image sensor when the CCD image sensor reads the sample sheet;

FIG. **7** is a graph of a relationship between an image density and an output voltage of an AIDC sensor showing an image density control process performed in the digital full color copying machine shown in FIGS. **1** and **2***a* to **2***c*;

FIGS. **8** and **9** are graphs of relationships between an image density and an output voltage of the AIDC sensor showing a modification of the image density control process performed in the digital full color copying machine shown in FIGS. **1** and **2***a* to **2***c*, respectively;

FIGS. **10***a*, and **10***b* are flow charts of a main routine executed by the printer controller of the digital full color copying machine shown in FIGS. **2***a* to **2***c*;

FIG. **11** is a flow chart of an initial value input process of a subroutine shown in FIG. **10***a*;

FIG. **12** is a flow chart of a modification of the initial value input process of the subroutine shown in FIG. **1**;

FIGS. **13***a* to **13***c* are flow charts of a sample sheet printing process of a subroutine shown in FIGS. **11** and **18**;

FIG. **14** is a flow chart of an ID measuring process of a subroutine shown in FIGS. **11** and **18**;

FIGS. **15***a* and **15***b* are flow charts of an AIDC measuring process of a subroutine shown in FIG. **10***a*;

FIG. **16** is a flow chart of a V_G and V_B selection process of a subroutine shown in FIG. **10***a*;

FIG. **17** is a flow chart of a γ correction table selection process of a subroutine shown in FIG. **10***a*;

FIG. 18 is a flow chart of an AIDC correction process of a subroutine shown in FIG. 10*b;*

FIGS. 19*a* and 19*b* are flow charts of a process for calculating an output voltage from AIDC sensor after there is shifted a relationship among an output voltage of an AIDC sensor, a grid voltage and a developing bias voltage, of a subroutine shown in FIG. 18;

FIG. 20 is a flow chart of a V_G and V_B table shift process of a subroutine shown in FIG. 18;

FIG. 21 is a flow chart of an initialization process of a subroutine shown in FIG. 10*b;*

FIGS. 22*a* to 22*d* are flow charts of a first warning process of a subroutine shown in FIG. 16; and

FIG. 23 is a flow chart of a second warning process of a subroutine shown in FIG. 18.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A digital full color copying machine according to one preferred embodiment of the present invention will be depicted hereinbelow with reference to the accompanying drawing in an order of the following items.

(a) Structure of Digital full color copying machine

(b) Processing of Image signal

(c) Image density control process

(d) Control flow of Printer controller

The features of the digital full color copying machine of the present preferred embodiment are as follows. After there is read an image of a sample sheet 300 on which there have been formed reference test pattern images of respective colors of cyan C, magenta M, yellow Y and black K having the maximum image density in the initial state of the copying machine immediately before shipping it from a factory after manufacturing it (referred to as an initial state hereinafter) and toner images of the respective colors corresponding to the reference test pattern images are then formed on the photoconductive drum 41, light amounts of reflected lights from the toner images formed on the photoconductive drum 41 are measured by the AIDC sensor 203, and then, data of the light amounts thereof are stored in a RAM 232 as initial AIDC data. Further, the printed sample sheet 300 is read by a CCD image sensor 14, and read density data DDm of the respective reference test pattern images formed on the sample sheet 300 are stored in a RAM 17 as initial read density data. Thereafter, an image density control process is carried out in a manner as will be described below on the basis of the initial AIDC data stored in the RAM 232, the initial read density data stored in the RAM 17, and an output voltage Vs of the AIDC sensor 203 when the operator turns on an AIDC correction switch 241 (referred to as an AIDC-CPSW in the drawings).

When the relationship between the original density and the image density is shifted from that in the initial state as a result of deterioration of developers of developing devices 45*a* to 45*d*, change in a sensitivity of the photoconductive drum 41 or change in the circumstances, a relationship among the output voltage Vs of the AIDC sensor 203, the grid voltage V_G of the corona charger 43 and the developing bias voltage V_B is shifted from that in the initial state. Therefore, the output voltage Vs of the AIDC sensor 203 to be shifted at this time is calculated, the grid voltage V_G and the developing bias voltage V_B in a V_G and V_B table for representing a relationship among the output voltage Vs of the AIDC sensor 203, the grid voltage V_G and the developing bias voltage V_B are so as to be shifted based on the calculated output voltage Vs.

Thereafter, upon performing a normal copying process, the copying process is performed by selecting a suitable one of plural γ correction tables on the basis of the corrected V_G and V_B table. In this case, the above-mentioned image density control process is performed so as to make the maximum image density of an image formed on a sheet of copying paper constant, thereby always forming a reproduced image having a constant gradation reproducibility for an original.

Furthermore, when one or more of the developing devices 45*a* to 45*d* are exchanged with new ones after the grid voltage V_G and the developing bias voltage V_B in the V_G and V_B table are set so as to be shifted as described above, the V_G and V_B table is initialized. More specifically, set values of the grid voltage V_G and the developing bias voltage V_B in the V_G and V_B table corresponding to the output voltage Vs are respectively shifted based on the shifted output voltage Vs of the AIDC sensor 203 into those in the above-mentioned initial state.

(a) Structure of digital full color copying machine

FIG. 1 is a longitudinal cross sectional view of the whole structure of the digital full color copying machine according to the present preferred embodiment of the present invention.

Referring to FIG. 1, the digital full color copying machine of the present preferred embodiment is mainly divided into two parts of an image reader part 1 for reading an image of an original (referred to as an original image hereinafter) and converting image signals of the read original image into image data for representing image densities of images of four colors of yellow (Y), magenta (M), cyan (C) and black (K), and a printer part 2 for printing the read original image on a sheet of copying paper based on the converted image data.

As shown in FIG. 1, a scanner 10 comprises an exposure lamp 12 for illuminating an original, a rod lens array 13 for condensing a reflected light from the original, and a contact type CCD color image sensor 14 for converting the original image of the condensed light into electric image signals. When the original is to be read, the scanner 10 is driven by a motor 11 so as to be moved in a subscan direction indicated by an arrow A1, thereby scanning the original placed on an original glass table 15. The original image on the original surface illuminated by the exposure lamp 12 is photoelectrically converted into image density signals by the image sensor 14. The image density signals for respectively representing the image densities of three colors of red (R), green (G) and blue (B) are converted into (8×4) bit gradation data of four colors of yellow Y, magenta M, cyan C and black K. Thereafter, a print head controller 202 performs a γ correction process and a dither process corresponding to gradation characteristics of the photoconductive drum 41 for the inputted gradation data, and then, a print head part 31 performs a digital to analogue conversion process (referred to as a D/A conversion process hereinafter) for image data for which the γ correction process and the dither process have been performed so as to generate an analogue laser diode driving signal. Thereafter, a laser diode 221 shown in FIGS. 2*b* and 3 is driven by the laser diode driving signal outputted from the print head part 31.

A beam of laser light emitted from the laser diode 221 in accordance with the gradation data is projected through a reflection mirror 37 onto the photoconductive drum **41** which is rotated in a direction as indicated by an arrow A2, thereby exposing the surfaces of the photoconductive drum **41** to the laser light. Then, the original image is formed on a photoconductor of the photoconductive drum **41**. The photoconductive drum **41** is illuminated by an eraser lamp **42** prior to the exposure of the laser light every one copying operation, and then, is electrically charged uniformly by the corona charger **43**. Therefore, when the photoconductive drum **41** in the uniformly charged state is exposed to a beam of laser light, an electrostatic latent image is formed on the photoconductive drum **41**. Thereafter, either one of the developing devices **45***a* to **45***d* which respectively include yellow, magenta, cyan and black toners is selected, and the selected one thereof develops the electrostatic latent image formed on the photoconductive drum **41** with toner so as to form a toner image. The toner image after completion of the development process is transferred by a transfer charger **46** onto a sheet of copying paper which is fed from a paper cassette **50**, and then is wound around a transfer drum **51**. On the other hand, the light amount of the reflected light from the developed toner image is optically detected by the AIDC sensor **203** provided at a position closer to the side of the developing device **45***d* than a transfer position at which the photoconductive drum **41** is in contact with the transfer drum **51**.

The above-mentioned printing process is repeated for every color of yellow, magenta, cyan and black. At that time, the scanner **10** repeatedly scans in synchronization with the rotation of the photoconductive drum **41** and the transfer drum **51**. Then, the copying paper is separated from the transfer drum **51** by a separating nail **47**, the toner image formed on the copying paper is fixed by a fixing device **48**, and then, the copying paper is discharged onto a discharge tray **49**. It is to be noted that the copying paper is supplied from the paper cassette **50**, an end of which is chucked by a chucking mechanism **52** provided on the transfer drum **51** so as to prevent any positional displacement of the copying paper upon the transfer.

FIGS. 2*a* to 2*c* are block diagrams of the whole of the digital full color copying machine of the present preferred embodiment.

Referring to FIG. 2*a*, an image reader controller **101** for controlling the operation of the image reader part **1** controls the exposure lamp **12** through a driving input and output interface circuit (referred to as a driving I/O hereinafter) **103** on the basis of a position signal from a position detecting switch **102** for showing a position of the original placed on the original glass table **15**. Further, the image reader controller **101** controls a scan motor driver **105** through the driving I/O **103** and a parallel input and output interface circuit (referred to as a parallel I/O hereinafter) **104**. The scan motor **11** is driven by the scan motor driver **105**.

On the other hand, the image reader controller **101** is electrically connected to an image controller **106** through a bus. The image controller **106** is electrically connected to the CCD color image sensor **14** and an image signal processing part **20** through respective buses. An image density signal Dm outputted from the CCD image sensor **14** is inputted to the image signal processing part **20**, and then, is processed by the image signal processing part **20** which will be depicted more in detail later.

Referring to FIGS. 2*b* and 2*c*, the printer part **2** comprises a printer controller **201** for controlling the copying process, and the print head controller **202** for controlling the print head part **31**.

To the printer controller **201**, there are inputted analogue electric signals outputted from a Vo sensor **44** for detecting the surface electric potential Vo prior to the exposure of the photoconductive drum **41**, a V_L sensor **60** for detecting the surface electric potential V_L immediately after the exposure of the photoconductive drum **41**, the AIDC sensor **203** for detecting the light amount of the reflected light from the toner image adhering onto the surface of the photoconductive drum **41**, an ATDC sensor **204** for detecting toner densities of toners provided within the developing devices **45***a* to **45***d*, and a temperature and humidity sensor (referred to as a TH sensor in the drawings) **205** through respective analogue to digital converters (referred to as A/D converters hereinafter) **44***a*, **60***a*, **203***a*, **204***a* and **205***a*.

It is to be noted that the analogue output voltage Vs outputted from the AIDC sensor **203** is converted into digital output voltage data DVs (referred to as an AIDC data) by the A/D converter **203***a*. The AIDC data DVs are inputted to not only the printer controller **201** but also a common terminal of a switch SW2 which is controlled to be switched over by the printer controller **201**. A terminal a of the switch SW2 is electrically connected to a buffer memory **231** for temporarily storing the output voltage data DVs, while a terminal b of the switch SW2 is electrically connected to a RAM **232** for storing the AIDC data Dvs of the AIDC sensor **203** detected in the above-mentioned initial state of the digital full color copying machine immediately before shipping it (referred to as initial AIDC data). The initial AIDC data stored in the RAM **232** are always retained by a backup battery B2 even when the digital full color copying machine is turned off. Both of the AIDC data read out from the buffer memory **231** and the initial AIDC data read out from the RAM **232** are inputted to a subtracter **233**, which calculates a difference of these data. Thereafter, data of the calculated difference are outputted to the printer controller **201**. Moreover, the initial AIDC data read out from the RAM **232** are directly inputted to the printer controller **201**.

An operation panel **206** comprises plural switches, namely, a print switch **240** for starting the copying operation, the AIDC correction switch **241** to be used when the AIDC correction process is carried out which will be described in detail later, and an ID measuring switch **242** (referred to as an ID-MPSW in the drawings) to be used in an ID measurement process which will be described in detail later. Information data outputted from the respective switches **240** to **242** of the operation panel **206** are inputted to the printer controller **201** through a parallel I/O **207**.

The printer controller **201** is electrically connected further to a control ROM **208***a* for storing a control program, a data ROM **208***b* for storing various kinds of data, and a RAM **209** for being used as a working area of the printer controller **201** and for storing various kinds of data such as V_G and V_B tables which are used for the copying process and the image density control process executed in the present preferred embodiment. The data stored in the RAM **209** are always retained by a backup battery B3 even through the digital full color copying machine is turned off. The V_G and V_B table as mentioned above is a table for showing a relationship among the output voltage Vs of the AIDC sensor **203**, the grid voltage V_G and the developing bias voltage V_B. Table 1 shows a V_G and V_B table in the above-mentioned initial state immediately before shipping the digital full color copying machine from the factory for manufacturing it.

Moreover, referring to FIG. 2*b*, read density data DDm obtained by analogue to digital converting the analogue image density signal Dm are inputted from the A/D converter **21** provided in the image signal processing part **20** of the image reader part **1** to a common terminal of a switch **SW1** which is controlled by the printer controller **201**. A terminal a of the switch **SW1** is electrically connected to a buffer memory **16** for temporarily storing the density data DDm, while a terminal b thereof is electrically connected to the RAM **17** for storing the read density data DDm (referred to as initial read density data hereinafter) obtained by analogue to digital converting the image density signal Dm which is outputted from the CCD image sensor **14** when a sample sheet is used immediately before the copying machine is shipped out from the factory. The initial read density data stored in the RAM **17** is always retained by a backup battery **B1** even if the digital full color copying machine is turned off. After both of the read density data read out from the buffer memory **16** and the initial read density data read out from the RAM **17** are inputted to a subtracter **18**, a difference of these data is calculated by the subtracter **18**, and then, data of the calculated difference are outputted to the printer controller **201**. The data read out from the RAM **17** are also inputted directly to the printer controller **201**.

Referring to FIG. 2*c*, the printer controller **201** performs an copying operation by controlling the copying controller **210** and the print head controller **202** according to the control program stored in the control ROM **208***a* based on various kinds of data outputted from the sensors **44**, **60** and **203** to **205**, the operation panel **206**, the data ROM **208***b*, the ROM **209**, the subtracters **18** and **233** and the RAM **232** for storing the initial AIDC data and the RAM **17** for storing the initial read density data. Upon the copying operation, the printer controller **201** outputs information data required for the copying operation to a display panel **211** so as to display them on the display panel **211**. It is to be noted that the display panel **211** comprises a warning light emitting diode (referred to as a warning LED hereinafter) **251** used in a first warning process shown in FIGS. **22***a* to **22***d*, and a warning LED **252** used in a second warning process shown in FIG. 23.

Further, as will be discussed in detail later, the printer controller **201** carries out the automatic image density control process, and then, controls a high voltage V_G generator **214** for generating the grid voltage V_G of the corona charger **43** and a high voltage V_B generator **215** for generating the developing bias voltage V_B of the developing roller **45***r* of the developing devices **45***a* to **45***d* shown in FIG. **5** through a parallel I/O **212** and a driving I/O **213**. During the image density control process, the printer controller **201** transmits data of set values of not only the grid voltage V_G corresponding to the surface electric potential Vo of the photoconductive drum **41** but also the developing bias voltage V_B to the print head controller **202**.

Referring to FIG. 2*b*, the print head controller **202** is electrically connected with a control ROM **216***a* for storing a control program, a data ROM **216***b* for storing various kinds of data, and a RAM **217** for being used as a working area of the print head controller **202** and for storing various kinds of data used for the γ correction process and the dither process as described later. The print head controller **202** is electrically connected to the printer controller **201** through a bus, and is also electrically connected to the image reader controller **101** and the image signal processing part **106** through respective image data buses. The print head controller **202** operates according to the control program stored in the control ROM **216***a*, and also performs the γ correction process for respective image data of four colors Y, M, C and K which are received from the image signal processing part **20** of the image reader part **1** through the image data bus with referring to the γ correction table stored in the data ROM **216***b* Moreover, if the multi-value dither matrix method is used for presenting the gradation, the print head controller **202** generates the print driving signal to the laser diode driver **220** of the print head part **31** through the driving I/O **218** and the parallel I/O **219**. Emission of a beam of laser light from the laser diode **221** is controlled by the laser diode driver **220** based on the print driving signal.

According to the present preferred embodiment, two methods can be used to express the gradation, that is, there can be used not only a multi-value laser exposure method such as the pulse width modulation method, the intensity modulation method or the like, but also a multi-value dither method which is a combination of the dither method and the pulse width modulation method or the intensity modulation method. Either one of the above two methods is selected by the operator using a gradation expression selection switch (not shown) which is provided the operation panel **206**.

Further, in the present preferred embodiment, in the case where there is used the multi-value laser exposure method according to the intensity modulation method or the pulse width modulation method, the print head controller **202** selects either one of plural γ correction tables stored in the data ROM **216***b* on the basis of the set value data of the grid voltage V_G and the developing bias voltage V_B which are received from the printer controller **201**. On the other hand, in the case where there is used the multi-value dither method, the print head controller **202** selects either one of plural dithers and performs the dither process using the selected dither.

(b) Processing of Image signal

FIG. **3** is a block diagram showing a processing flow of the image signals which are transmitted from the CCD image sensor **14** through the image signal processing part **20** and the print head controller **202** to the print head **31**. Referring now to FIG. **3**, there will be described below processing of the image signal, that is, how to process the image density signal Dm outputted from the CCD color image sensor **14**, thereby generating the print driving signal for driving the laser diode **221**.

In the image signal processing part **20**, the image density signals Dm of signals R, G and B photoelectrically converted by the CCD color image sensor **14** are inputted to the A/D converter **21**, and then, are converted into (8×3) bit digital read density data DDm of respective colors R, G and B composed of image data R', G' and B'. Thereafter, the read density data DDm of respective colors are inputted to a shading correction circuit **22** for performing a predetermined shading correction. Since the image data R'', G'' and B'' after completion of the shading correction are data of reflected light amounts obtained by reading images of the reflected lights from the original using the CCD image sensor **14**, a logarithmic conversion circuit **23** carries out a logarithmic conversion process for the inputted image data, thereby converting them into image data for indicating the actual density of the original image. Thereafter, an under color removal and black adding circuit **24** performs an under color removal process and a black adding process for the inputted image data, thereby removing unnecessary black components from the inputted image data and also generating black image data K based on the inputted image data of three colors R, G and B. Thereafter, a masking circuit **25** performs a masking process for the image data of three colors R, G and B inputted from the under color removal and black adding circuit **24**, thereby converting them into image data of three colors yellow Y, magenta M and cyan C. Then, a density correction circuit **26** performs a density correction process for multiplying the image data of three colors Y, M and C converted by the masking circuit **25** by predetermined coefficients. Thereafter, a spatial frequency correction circuit **27** performs a predetermined spatial frequency correction process known to those skilled in the art for respective image data after completion of the density correction process, and outputs respective image data of four colors yellow Y, magenta M, cyan C and black K after completion thereof to a γ correction circuit **28** of the print head controller **202**.

The γ correction circuit **28** performs a γ correction process for the respective image data of four colors Y, M, C and K outputted from the spatial frequency correction circuit **27** using the γ correction table provided in the data ROM **216***b*. Thereafter, if the multi-value dither method is used to express the gradation, a dither circuit **29** performs a dither process for the inputted image data based on the dither threshold table stored in the data ROM **216***b*, and then, outputs a print driving signal after completion of the dither process to the laser diode driver **220** of the print head part **31**. In the data ROM **206***b* connected to the print head controller **202**, there are stored plural γ correction tables used in the above-mentioned γ correction process and plural dither threshold tables used in the dither process. Thereafter, there are selected either one of these γ correction tables and either one of the dither threshold tables on the basis of the set value data of the grid voltage V_G and the developing bias voltage V_B which are received from the printer controller **201**, and then, the above-mentioned γ correction and the above-mentioned dither process are performed using the selected tables.

(c) Image density control process

In the present preferred embodiment, there is performed the above-mentioned γ correction process, however, as one of phenomena due to another cause for influencing the image density, there is such a phenomenon that an adhering amount of toner onto the photoconductive drum **41** changes upon the developing process using the toner when characteristics of the photoconductor and the toner changes due to change in external circumstances such as the temperature, the humidity, etc. Generally speaking, the following is known to those skilled in the art in this case. Namely, the adhering amount of toner increases under circumstances of a high temperature and a high humidity so that the original image having a higher image density is reproduced with a γ characteristic having a relatively large gradient in a relatively high original density. On the other hand, the adhering amount of toner decreases under circumstances of a low temperature and a low humidity so that the original image having a lower image density is reproduced with a γ characteristic having a relatively small gradient in relatively low and middle original densities.

Thus, there is such a problem that the reproduced image density changes due to change in the circumstances. In order to solve the above-mentioned problem so as to obtain a stable proper image density, the following image density control process is performed in the present preferred embodiment.

In the digital full color copying machine of the present preferred embodiment, the toner densities of the respective color developers provided in the developing devices **45***a* to **45***d* are detected by the ATDC sensor **204** shown in FIG. **2***c*, and then, the toner densities of the respective developers are controlled so as to be constant by a conventional automatic toner density control process (referred to as an ATDC process hereinafter) known to those skilled in the art, based on the detected toner densities of the respective developers. Further, after the light amounts of the reflected lights from four color toner images C, M, Y and K of the reference test pattern formed on the photoconductive drum **41** are measured by the AIDC sensor **203**, the grid voltage V_G and the developing bias voltage V_B of the corona charger **43** are changed based on the measured light amounts so as to making the image density upon performing the copying operation in the digital full color copying machine constant, in spite of change in the circumstances.

The relationship among the output voltage Vs of the AIDC sensor **203**, the grid voltage V_G and the developing bias voltage V_B is stored as the V_G and V_B table in the RAM **209** for respective four colors cyan C, magenta M, yellow Y and black K. The V_G and V_B table in the initial state is shown in Table 1. As is apparent from Table 1, set values of the combinations of the grid voltage V_G and the developing bias voltage V_B corresponding to respective ones of the output voltage Vs of the AIDC sensor **203** are previously prepared as plural tables. The V_G and V_B tables are stored in the RAM **209** every color of four colors cyan C, magenta M, yellow γ and black K.

The image density control process to be performed in the digital full color copying machine of the present preferred embodiment will be described below in detail.

(1) As shown in FIG. **6**, in the initial state of the digital full color copying machine immediately before shipping out it from the factory, while there is printed the sample sheet **300** having reference test pattern images of four colors C, M, Y and K formed thereon, the image densities of the toner images of four colors formed on the photoconductive drum **41** are measured by the AIDC sensor **203**. The AIDC data Dvs corresponding to the measured image densities are stored as the initial AIDC data in the RAM **232**, while the printed sample sheet **300** are read by the CCD image sensor **14** and then the read density data DDm of the reference test pattern images of four colors included in the sample sheet **300** are stored as the initial read density data in the RAM **17**. Thereafter, images of the sample sheet **300** is read and the reference test pattern toner images of four colors corresponding to the read images are formed on the photoconductive drum **41**, and then, light amounts of reflected lights from the respective toner images are measured by the AIDC sensor **203**. The measured AIDC data DVs are stored as the initial AIDC data in the RAM **232**.

(2) A characteristic curve **401** of FIG. **7** shows a relationship between the image density of each color and the output voltage Vs of the AIDC sensor **203** in the initial state. As shown in FIG. **7**, as the image density becomes larger, the output voltage Vs is larger.

It is assumed that a characteristic point of the output voltage Vs of the AIDC sensor **203** on the characteristic curve **401** is P1 and the corresponding output voltage Vs is Vso, when an image density of a color measured with use of the sample sheet **300** is Do in the initial state. Thereafter, when the original density and the image density are respectively shifted from those in the initial state due to deterioration of the developers, change in the sensitivity of the photoconductive drum **41**, or change in the circumstances (referred to as a time of characteristic changed hereinafter), it is assumed that the above-mentioned characteristic curve **401** changes to a characteristic curve **402** as shown in FIG. **7**. At that time, when the AIDC measuring process is performed using the sample sheet **300**, it is assumed that an image density of a color becomes Dx, a characteristic point of the output voltage Vs of the AIDC sensor **203** is P2 at that time, and the output voltage Vs becomes Vsx.

At the time of characteristic changed, the image density in the copying process should be the image density Do of the initial state, and therefore, the characteristic point at that time should be positioned at P3 in the output voltage Vs of the AIDC sensor **203** to the image density characteristic shown in FIG. **7**. In other words, it is necessary to shift the characteristic point P2 to P3 on the characteristic curve **402**. The output voltage Vs of the AIDC sensor **203** at the characteristic point P3 after shifting the characteristic point is expressed by the following approximate equation:

$$Vsxo \approx \frac{Do}{Dx} \cdot Vsx \tag{1}$$

In the present preferred embodiment, when an absolute value $|Dx-Do|$ of the shift amount of the image density is larger than a predetermined threshold value ΔD, the calculation of the above equation (1) is performed for every color of four colors C, M, Y and K. Approximation calculations for each color corresponding to the above equation (1) are expressed as follows:

$$Vsxco \approx \frac{Dco}{Dcx} \cdot Vscx \tag{2a}$$

$$Vsxmo \approx \frac{Dmo}{Dmx} \cdot Vsmx \tag{2b}$$

$$Vsxyo \approx \frac{Dyo}{Dyx} \cdot Vsyx \tag{2c}$$

$$Vsxko \approx \frac{Dko}{Dkx} \cdot Vskx \tag{2d}$$

(3) Subsequently, on the basis of the output voltage Vs of the AIDC sensor **203** at the characteristic point P3 after shifting the characteristic point, set values of the grid voltage V_G and the developing bias voltage V_B corresponding to the output voltage Vs in the V_G and V_B table for each color are respectively shifted from those the initial state shown in Table 1 to those shown in Table 2. This process is referred to as an AIDC correction process hereinafter. Thereafter, upon starting a normal copying process, a suitable γ correction table is selected from plural tables based on the above corrected V_G and V_B table. Accordingly, it always becomes possible to reproduce an original image having a constant gradation reproducibility for the original.

(4) In the present preferred embodiment, when the developing devices **45*a*** to **45*d*** are exchanged with new ones after performing the AIDC correction process, there is performed an initialization process of the V_G and V_B table. More specifically, the set values of the grid voltage V_G and the developing bias voltage V_B corresponding to the output voltage Vs in the V_G and V_B table for each color are respectively shifted to the set values in the initial state shown in Table 1 based on the output voltage Vs of the AIDC sensor **203** at the shifted characteristic point P3 calculated in the AIDC correction process.

(d) Controlling flow of printer controller

FIGS. **10*a*** and **10*b*** are flow charts of a main routine executed by the printer controller **201** of the digital full color copying machine of the present preferred embodiment.

In step **1** of the main routine shown in FIG. **10*a***, when the ID measuring switch **242** is turned on, an initial value input process is started, and then, there are stored not only the initial AIDC data in the initial state immediately before shipping the copying machine but also the initial read density data. Processes of steps **S2** to **S8** are started when the print switch **240** is turned on so as to perform a normal copying operation. The image density control process of the present preferred embodiment is carried out in steps **S9** and **S10** shown in FIG. **10*b*** by turning on the AIDC correction switch **241**. The V_G and V_B table is initialized in an initialization process of steps **S11** and **S12** when the developing devices **45*a*** to **45*d*** are exchanged wit new ones.

Referring to FIGS. **10*a***, in the main routine of the print controller **201**, after the initial values are inputted in step **S1**, it is checked in step **S2** whether or not the print switch **240** is turned on. When the print switch **240** is turned on (YES in step **S2**), the program flow moves to step **S3**. On the other hand, if the print switch **240** is not turned on (NO in step **S2**), the program flow moves to step **S9** of FIG. **10*a***.

After performing the AIDC measuring process in step **S3** wherein the output voltage Vs of the AIDC sensor **203** is detected in order to measure the light amounts of the reflected lights from the toner images formed on the photoconductive drum **41**, there is performed the V_G and V_B selection process for selecting the grid voltage V_G and the developing bias voltage V_B using the V_G and V_B table presently stored in the RAM **209** based on the measured output voltage Vs in step **S4**. Thereafter, data detected by various sensors **44**, **66** and **203** to **205** are stored in the RAM **209** in step **S5**, and then, a suitable γ correction table is selected in step **S6** from the plural γ correction tables on the basis of the grid voltage V_G and the developing bias voltage V_B selected in the V_G and V_B selection process. Furthermore, after there is performed the copying process for copying an original placed on the original glass table **15** in step **S7**, the program flow goes to step **S8**.

It is checked in step **S8** whether or not the copying process is completed. If the copying process is completed (YES in step **S8**), the program flow advances to step **S9** of FIG. **10*b***. If the copying process is not completed (NO in step **S8**), the program flow returns to step **S4**.

In step **S9**, it is detected whether or not the AIDC correction switch **241** is turned on. When the AIDC correction switch **241** is turned on (YES in step S9), the AIDC correction process is carried out in step S10, and then, the program flow proceeds to step S11. On the other hand, when the AIDC correction switch **241** is not turned on (NO in step S9), the program flow moves to step S11.

In step S11, it is detected whether or not the developing devices **45***a* to **45***d* are exchanged with new ones. When the developing devices **45***a* to **45***d* are exchanged with new ones (YES in step S11), the above-mentioned initialization process is performed in step S12, and then, the program flow returns to step S2. On the other hand, if the developing devices **45***a* to **45***d* are not exchanged with new ones (NO in step S11), the program flow returns to step S2.

FIG. **11** is a flow chart of the initial value input process of the subroutine (step S1) shown in FIG. **10***a*.

Referring to FIG. **11**, it is checked first in step S101 whether or not the ID measuring switch **242** is turned on. If the ID measuring switch **242** is turned on (YES in step S101), the program flow proceeds to step S102. In step S102, after printing the sample sheet **300** on which the reference test pattern images of four colors C, M, Y and K shown in FIG. **6** are formed, the program flow moves to step S103. On the other hand, if the ID measuring switch **242** is not turned on (NO in step S101), the program flow returns to the original main routine.

Prior to step S103, the operator places the printed sample sheet **300** onto the original glass table **15** and turns on the ID measuring switch **242** in order to perform processes from step S104 and afterwards.

It is judged in step S103 whether or not the ID measuring switch **242** is turned on. When the ID measuring switch **242** is not turned on (NO in step S103), the copying machine is kept waiting until the ID measuring switch **242** is turned on in step S103. On the other hand, the ID measuring switch **242** is turned on (YES in step S103), both the switches SW1 and SW2 are switched over to the terminal b in step S104. Thereafter, the program flow moves to step S105, and then, there is performed the ID measuring process for measuring the light amounts of the reflected lights from the images of four colors of the printed sample sheet **300**.

Thereafter, in step S107, the read density data Dcx, Dmx, Dyx and Dkx of four colors C, M, Y and K which are measured in the preceding ID measuring process of step S105 are respectively stored as the initial read density data Dco, Dmo, Dyo and Dko in the RAM **17**. Then, in step S108, the AIDC data DVscx, DVsmx, DVsyx and DVskx which are data of the output voltages Vs of the AIDC sensor **203** of four colors C, M, Y and K measured in the AIDC measuring process are respectively stored as the initial AIDC data Vsco, Vsmo, Vsyo and Vsko in the RAM **232**. Finally, after the switches SW1 and SW2 are switched over to the terminal a in step S109, the program flow goes back to the original main routine.

FIG. **12** is a flow chart of a modification of the initial value input process of the subroutine (step S1) shown in FIG. **11**. In the modified initial value input process, the copying process is performed for the already printed sample sheet **300**, and then, processes are performed using the copy of the sample sheet **300** in manners similar to those of steps S105 to S108 shown in FIG. **11**.

Referring to FIG. **12**, it is checked in step S111 whether or not the ID measuring switch **242** is turned on. If the ID measuring switch **242** is turned on (YES in step S111), the program flow goes to step S112, and then, the copying process is performed for the already printed sample sheet **300**, the program flow going to step S113. On the other hand, when the ID measuring switch **242** is not turned on (NO in step S111), the program flow returns to the main routine, directly.

Prior to step S113, the operator puts the copied sample sheet on the original glass table **15**, and then, turns on the ID measuring switch **242** in order to perform the processes from step S114 and afterwards.

It is detected in step S113 whether or not the ID measuring switch **242** is turned on. If the ID measuring switch **242** is not turned on (NO in step S113), the copying machine becomes a waiting state in step S113 until the ID measuring switch **242** is turned on. Further, if the ID measuring switch **242** is turned on (YES in step S113), both the switches SW1 and SW2 are switched over to the terminal b in step S114, and then, the program flow proceeds to step S115. After processes of S115, S117 and S118 are carried out in manners similar to those of steps S105, S107 and S108 shown in FIG. **11**, both the switches SW1 and SW2 are switched over to the terminal a in step S119, and then, the program flow returns to the original main routine.

FIGS. **13***a* to **13***c* are flow charts of the sample sheet printing process of the subroutine (steps S102 and S701) shown in FIGS. **11** and **18**.

Referring to FIG. **13***a*, after standard values are set respectively as the grid voltage V_G and the developing bias voltage V_B in step S201, the cyan developing device **45***c* is set and a color indicating parameter DN is set to zero in step S202. Thereafter, in step S203, the photoconductive drum **41** is rotated, both of the corona charger **43** and eraser lamp **42** are turned on, and further, the presently set developing device is turned on. Then, the photoconductive drum **41** is exposed to a beam of laser light emitted from the laser diode **221** provided in the print head part **31** in step S204. In step S205, a light amount of a reflected light from a toner image formed on the photoconductive drum **41** by the exposure of a beam of laser light is measured by the AIDC sensor **203**, and then, the output data DVs from the AIDC sensor **203** are stored in the RAM **209** as the AIDC data DVsx. Thereafter, the color indicating parameter DN is incremented by one in step S206 so that the added result is made the updated color indicating parameter DN. Further, the program flow goes to step S207.

It is checked in steps S207, S208 and S209 whether the color indicating parameter DN is 1, 2 or 3, respectively.

When the color indicating parameter DN is 1 (YES in step S207), the AIDC data DVsx are stored as the cyan AIDC data DVscx in the RAM **209** in step S211. Thereafter, the exposure of a beam of laser light is stopped in step S212, and then, the cyan pattern image formed on the photoconductive drum **41** is transferred onto a sheet of copying paper in step S213. Thereafter, the position for forming a pattern image is shifted in step S214 so as to form the following magenta pattern image, and then, a detection timing of the AIDC sensor **203** is shifted in step S215 to detect the following magenta pattern image. Further, the cyan developing device **45***c* is turned off in step S216, and also the magenta developing device **45***b* is set. Thereafter, the program flow goes back to step S203.

Referring to FIG. **13***b*, when the color indicating parameter DN is 2 (YES in step S208), the AIDC data DVsx are stored in step S221 as the magenta AIDC data DVsmx in the RAM **209**, and then, emission of a beam of laser light is stopped in step S222. Thereafter, the magenta pattern image formed on the photoconductive drum 41 is transferred onto the copying paper in step S223. Then, the position for forming the pattern image is shifted in step S224 so as to form the yellow pattern image, and then, the detection timing of the AIDC sensor 203 is shifted in step S225 to detect the yellow pattern image. Further, the magenta developing device 45b is turned off in step S226, and then, the yellow developing device 45a is set. Thereafter, the program flow returns to step S203.

If the color indicating parameter DN is three (YES in step S209), the AIDC data DVsx are stored as the yellow AIDC data DVsyx in the RAM 209 in step S231, the exposure of a beam of laser light is stopped in step S232, and then, the yellow pattern image formed on the photoconductive drum 41 is transferred onto the copying paper in step S233. Thereafter, the position for forming the pattern image is shifted in step S234 so as to form the black pattern image, and also the detection timing of the AIDC sensor 203 is shifted in step S235 to detect the following black pattern image. Further, the yellow developing device 45a is turned off, and the black developing device 45d is set in step S236. Thereafter, the program flow returns to step S203.

When the color indicating parameter DN is not any one of 1, 2 and 3 (NO in all steps S207, S208 and S209), the AIDC data Dvsx are stored as the black AIDC data Dvskx in the RAM 209 in step S241 shown in FIG. 13c, and then, the exposure of a beam of laser light is stopped in step S242. Thereafter, the black pattern image formed on the photoconductive drum 41 is transferred onto the copying paper in step S243, and then, the other printing processes are performed in step S244. Further, the program flow returns to the original routine.

FIG. 14 is a flow chart of the ID measuring process of the subroutine (steps S105 and S703) shown in FIGS. 11 and 18.

Referring to FIG. 14, the scan operation is performed by the scanner 10 so as to read the original image in step S301, and then, it is judged in steps S302, S303 and S304 whether it is one of the scans for reading images of cyan, magenta and yellow, respectively.

If it is judged to be the scan for reading an image of cyan (YES in step S302), the read density data DDm which are detected by the CCD image sensor 14 and converted by the A/D converter 21 are stored as the cyan read density data Dcx in the RAM 209 in step S311, and then, the program flow goes to step S315. If it is the scan for reading an image of magenta (YES in step S303), the read density data DDm which are detected by the CCD image sensor 14 and converted by the A/D converter 21 are stored as the magenta read density data Dmx in the RAM 209 in step S312, and then, the program flow proceeds to step S315. Further, if it is judged to be the scan for reading an image of yellow (YES in step S304), the read density data DDm which are detected by the CCD image sensor 14 and converted by the A/D converter 21 are stored as the yellow read density data Dyx in the RAM 209 in step S313, and then, the program flow goes to step S315. Moreover, if it is judged that it is not the scan for reading images of cyan, magenta and yellow (NO in all steps S302, S303 and S304), the read density data DDm which are detected by the CCD image sensor 14 and converted by the A/D converter 21 are stored as the black read density data Dkx in the RAM 209 in step S314, and then, the program flow goes to step S315.

In step S315, it is detected whether or not the scans for reading the images of four colors are completed. If it is not detected that the scans for reading the images of four colors are completed (NO in step S315), the program flow moves back to step S301. Otherwise, the program flow returns to the original routine when the scans therefor are completed (YES in step S315).

FIGS. 15a and 15b are flow charts of the AIDC measuring process of the subroutine (steps S3) shown in FIG. 10a.

Referring to FIG. 15a, after the standard values of the grid voltage V_G and the developing bias voltage V_B are set in step S401, the cyan developing device 45c is set and also the color indicating parameter DN is set to zero in step S402. The program flow proceeds to step S403, wherein the photoconductive drum 41 is rotated, and both of the corona charger 43 and the eraser lamp 42 are turned on. In the following step S404, the photoconductive drum 41 is exposed to a beam of laser light emitted from the laser diode 221 of the print head part 31. Thereafter, the light amount of the reflected light from the toner image formed on the photoconductive drum 41 by the exposure of a beam of laser light in step S404 is measured by the AIDC sensor 203 in step S405, and then, the output data DVs from the AIDC sensor 203 are stored as the AIDC data DVsx in the RAM 209. Thereafter, the color indicating parameter DN is incremented by one in step S406, so that the adding result is made the updated color indicating parameter DN. Then, the program flow proceeds to step S407.

In steps S407, S408 and S409, it is checked whether the color indicating parameter DN is 1, 2 and 3, respectively.

If the color indicating parameter DN is 1 (YES in step S407), the AIDC data DVsx are stored as the cyan AIDC data DVscx in the RAM 209 in step S411, and then, the exposure of a beam of laser light is stopped in step S412. Thereafter, the cyan developing device 45c is turned off, and also the magenta developing device 45b is set in step S413. Subsequently, the program flow returns to step S403.

Referring to FIG. 15b, when the color indicating parameter DN is 2 (YES in step S408), the AIDC data DVsx are stored as the magenta AIDC data DVsmx in the RAM 209 in step S421, and then, the exposure of a beam of laser light is stopped in step S422. Thereafter, the magenta developing device 45b is turned off and the yellow developing device 45a is set in step S423. Further, the program flow returns to step S403.

When the color indicating parameter DN is 3 (YES in step S409), the AIDC data DVsx are stored as the yellow AIDC data DVsyx in the RAM 209 in step S431, and then, the exposure of a beam of laser light is stopped in step S432. Thereafter, in step S433, the yellow developing device 45a is turned off, and then, the black developing device 45d is set. Further, the program flow moves back to step S403.

When the color indicating parameter DN is not any one of 1, 2, and 3 (NO in all steps S407, S408 and S409), the AIDC data DVsx are stored as the black AIDC data Dvskx in the ram 209 in step S441, and then, the exposure of a beam of laser light is stopped in step S442. Further, the program flow returns to the original routine.

FIG. 16 is a flow chart of the V_G and V_B selection process of the subroutine (step S4) shown in FIG. 10a.

Referring to FIG. 16, it is detected first in step S501 whether or not there has been switched the color of the image to be formed. If the color thereof has been switched (YES in step S501), the program flow advances to step S502. On the other hand, if the color thereof has not been switched (NO in step S501), the program flow returns to step S510. It is checked in steps S502, S503 and S504 whether they are the scans for reading images of cyan, magenta and yellow, respectively.

When it is the scan for reading an image of cyan (YES in step S502), the AIDC data DVscx detected by the AIDC sensor **203** are stored as data Vss in the RAM **209** in step S505, and then, the program flow moves to step S509. Moreover, if it is the scan for reading an image of magenta (YES in step S503), the AIDC data Dvsmx detected by the AIDC sensor **203** are stored as data Vss in the RAM **209** in step S506, and then, the program flow goes to step S509. Further, if it is the scan for reading an image of yellow (YES in step S504), the AIDC data DVsyx detected by the AIDC sensor **203** are stored in step S507 as data Vss in the RAM **209**, and then, the program flow goes to step S509. However, if it is not judged to be any one of the scans for reading images of cyan, magenta and yellow (NO in all steps S502, S503 and S504), the AIDC data DVskx detected by the AIDC sensor **203** are stored as data Vss in the RAM **209** in step S508, and then, the program flow goes to step S509.

In step S509, based on the data Vss with respect to the output voltage Vs of the AIDC sensor **203** which are stored in the RAM **209**, the grid voltage V_G and the developing bias voltage V_B are selected and set using the V_G and V_B table currently stored in the RAM **209**, and then, there is performed in step S510 a first warning process shown in FIGS. *22a*to *22d* for warning to the operator that the selected grid voltage V_G and the selected developing bias voltage V_B are the maximum or minimum values, which will be described in detail later. Thereafter, the program flow returns to the main routine.

FIG. **17** is a flow chart of the γ correction table selection process of the subroutine (step S6) shown in FIG. **10***a*.

Referring to FIG. **17**, first of all, it is detected in step S601 whether or not there has been switched the color of the image to be formed. If the color thereof has been switched (YES in step S601), the program flow moves to step S602. Otherwise, the program flow moves back to the original routine. In step S602, a suitable γ correction table is selected from the plural γ correction tables according to a publicly known method based on the selected grid voltage V_G and the selected developing bias voltage V_B, and then, the program flow goes back to the main routine.

FIG. **18** is a flow chart of the AIDC correction process of the subroutine (step S10) shown in FIG. **10***a*.

Referring to FIG. **18**, first of all, the above-mentioned sample sheet printing process is performed in step S701, and then, it is checked in step S702 whether or not the AIDC correction switch **241** is turned on. If the AIDC correction switch **241** is not turned on (NO in step S702), the copying machine becomes a waiting state until the AIDC correction switch **241** is turned on. When the AIDC correction switch **242** is turned on (YES in step S702), the ID measuring process is performed in step S703, and then, the program flow moves to step S704.

It becomes necessary to correct the relationship among the output voltage Vs of the AIDC sensor **203**, the grid voltage V_G and the developing bias voltage V_B if the relationship thereamong changes due to change in the circumstances. Therefore, there is performed in step S704 a process for calculating the output voltage Vs of the AIDC sensor **203** after the shift of the above-mentioned relationship in order to correct the above-mentioned relationship, and then, there is performed in step S706 a second warning process shown in FIG. **23** for warning the operator that a difference between the output voltage Vsxo of the AIDC sensor **203** after the shift of the above-mentioned relationship and that Vso in the initial state, which will be described in detail later. Thereafter, there is performed the V_G and V_B shift process in step S705 for shifting the grid voltage V_G and the developing bias voltage V_B corresponding to the output voltage Vs of the AIDC sensor **203** in the V_G and V_B table so as to obtain a reproduced image having a constant gradation reproducibility for the original, based on the calculated output voltage Vs of the AIDC sensor **203** after the shift thereof. Thereafter, the program flow returns to the original main routine.

FIGS. **19***a* and **19***b* are flow charts of the process for calculating the output voltage from the AIDC sensor **203** after there is shifted the relationship among the output voltage from the AIDC sensor **203**, the grid voltage V_G and the developing bias voltage V_B, of the subroutine (step S704) shown in FIG. **18**.

Referring to FIG. **19***a*, in step S801, there is calculated an absolute value of a difference between the read density data Dcx of cyan measured in the ID measuring process and the initial read density data Dco stored in the RAM **17** by the subtracter **18**, and then, it is judged whether or not the calculated absolute value is larger than a predetermined threshold value ΔD. When the calculated absolute value is larger than the threshold value ΔD (YES in step S801), the program flow proceeds to step S802. Otherwise, the program flow moves to step S803. In step S802, the right side of the above equation (2a) is calculated, and then, data of the calculated result thereof are stored in the RAM **209** as the output voltage data Vsxco of the AIDC sensor **203** after the shift. Thereafter, the program flow goes to step S811. On the other hand, in step S803, the initial AIDC data Vsco of cyan stored in the RAM **232** are stored in the RAM **209** as the output voltage data Vsxco of the AIDC sensor **203** after the shift, and then, the program flow moves to step S811.

In step S811, an absolute value of a difference between the read density data Dmx of magenta measured in the ID measuring process and the initial read density data Dmo is calculated by the subtracter **18**, and then, it is detected whether or not the calculated absolute value thereof is larger than the predetermined value ΔD. If the calculated absolute value thereof is larger than the predetermined threshold value ΔD (YES in step S811), the program flow goes to step S812. Otherwise, the program flow goes to step S813. In step S812, the right side of the above equation (*2*b) is calculated, and data of the calculated result are stored in the RAM **209** as the output voltage data Vsxmo of the AIDC sensor **203** after the shift. Thereafter, program flow moves to step S821 of FIG. **19***b*. On the other hand, in step S813, the initial AIDC data Vsmo of magenta stored in the RAM **232** are stored in the RAM **209** as the output voltage data Vsxmo of the AIDC sensor **203** after the shift, and then, the program flow goes to step S821 of FIG. **19***b*.

In the succeeding step S821 of FIG. **19***b*, an absolute value of a difference between the read density data Dyx of yellow measured in the ID measuring process and the initial read density data Dyo stored in the RAM **17** is calculated by the subtracter **18**, and then, it is judged whether or not the calculated absolute value thereof is larger than the predetermined threshold value ΔD. If the calculated absolute value thereof is larger than the predetermined threshold value ΔD (YES in step **S821**), the program flow moves to step **S822**. On the other hand, if the calculated absolute value thereof is equal to or smaller than the predetermined threshold value ΔD (NO in step **S821**), the program flow proceeds to step **S823**. In step **S822**, the right side of the above equation (2c) is calculated, and then, data of the calculated result thereof are stored in the RAM **209** as the output voltage data Vsxyo of the AIDC sensor after the shift. Thereafter, the program flow goes to step **S831**. Further, in step **S823**, the initial AIDC data Vsyo of yellow stored in the RAM **232** are stored in the RAM **209** as the output voltage data Vsxyo of the AIDC sensor **203** after the shift, and then, the program flow subsequently goes to step **S831**.

In step **S831**, an absolute value of a difference between the read density data Dkx of black measured in the above ID measuring process and the initial read density data Dko stored in the RAM **17** is calculated by the subtracter **18**, and then, it is judged whether or not the calculated absolute value thereof is larger than the predetermined threshold value ΔD. If the calculated absolute value thereof is larger than the predetermined threshold value ΔD (YES in step **S831**), the program flow goes to step **S832**. On the other hand, if the calculated absolute value thereof is not larger than the predetermined threshold value ΔD (NO in step **S831**), the program flow moves to step **S833**. In step **S832**, the right side of the above equation (2d) is calculated, and then, data of the calculated result are stored in the RAM **209** as the output voltage data Vsxko of the AIDC sensor **203** after the shift. Thereafter, the program flow returns to the original routine. In step **S833**, the initial AIDC data Vsko of black stored in the RAM **232** are stored as the output voltage data Vsxko of the AIDC sensor **203** after the shift, and then, the program flow returns to the original routine.

FIG. **20** is a flow chart of the V_G and V_B table shift process of the subroutine (step **S705**) shown in FIG. **18**.

Referring to FIG. **20**, as shown in Table 2, the grid voltage V_G and the developing bias voltage V_B in the V_G and V_B table of cyan are respectively shifted in step **S901** so as to be set to the grid voltage V_Go in the initial state and the developing bias voltage V_Bo in the initial state upon the output voltage data Vsxco of the AIDC sensor **203** with respect to the image of cyan after the shift which are calculated in the process shown in FIG. **19***a*. For example, when a table No. 6 in Table 1 for showing the V_Go and V_B table in the initial state is a table selected in the initial state, the initial grid voltage V_Go is 650 V and the initial developing bias voltage V_Bo is 400 V.

Thereafter, in step **S902**, as shown in table 2, the grid voltage V_G and the developing bias voltage V_B in the V_G and V_B table of magenta are respectively shifted to be set the grid voltage V_Go in the initial state and the developing bias voltage V_Bo in the initial state upon the output voltage data Vsxmo of the AIDC sensor **203** with respect to the image of magenta after the shift which are calculated in the process shown in FIG. **19***a*.

Thereafter, in step **S903**, as shown in Table 2, the grid voltage V_G and the developing bias voltage V_B in the V_G and V_B table of yellow are respectively shifted to be set the grid voltage V_Go in the initial state and the developing bias voltage V_Bo in the initial state upon the output voltage data Vsxyo of the AIDC sensor **203** with respect to the image of yellow after the shift which are calculated in the process shown in FIG. **19***b*.

In the next step **S904**, as shown in Table 2, the grid voltage V_G and the developing bias voltage V_B in the V_G and V_B table of black are respectively shifted to be set the grid voltage V_Go in the initial state and the developing bias voltage V_Bo in the initial state upon the output voltage data Vsxko of the AIDC sensor **203** with respect to the image of black after the shift which are calculated in the process shown in FIG. **19***b*. Thereafter, the program flow returns to the original main routine.

FIG. **21** is a flow chart of the initialization process of the subroutine (step **S12**) shown in FIG. **10***b*.

In step **S1001** of FIG. **21**, as shown in Table 1, the grid voltage V_G and the developing bias voltage V_B in the V_G and V_B table of cyan presently stored in the RAM **209** are respectively shifted to be set the grid voltage V_Go in the initial state and the developing bias voltage V_Bo in the initial state upon the initial AIDC data Vsco. Thereafter, in step **S1002**, as shown in Table 1, the grid voltage V_G and the developing bias voltage V_B in the V_G and V_B table of magenta presently stored in the RAM **209** are respectively shifted to be set the grid voltage V_Go in the initial state and the developing bias voltage V_Bo in the initial state upon the initial AIDC data Vsmo. Thereafter, in step **S1003**, as shown in Table 1, the grid voltage V_G and the developing bias voltage V_B in the V_G and V_B table of yellow presently stored in the RAM **209** are respectively shifted to be set the grid voltage V_Go in the initial state and the developing bias voltage V_Bo in the initial state upon the initial AIDC data Vsyo. Thereafter, in step **S1004**, as shown in Table 1, the grid voltage V_G and the developing bias voltage V_B in the V_G and V_B table of black presently stored in the RAM **209** are respectively shifted to be set the grid voltage V_Go in the initial state and the developing bias voltage V_Bo in the initial state upon the initial AIDC data Vsko. Then, the program flow returns to the main routine.

FIGS. **22***a* to **22***d* are flow charts of the first warning process of the subroutine shown in FIG. **16**. It is to be noted that the grid voltage V_G and the developing bias voltage V_B to be set are previously determined in the present preferred embodiment, for example, as shown in Tables 1 and 2.

Referring to FIG. **22***a*, it is judged in step **S1101** whether or not the output voltage Vsxco of the AIDC sensor **203** after the shift of the above-mentioned relationship is larger than the output voltage Vsco thereof in the initial state, upon forming an image of cyan. If the output voltage Vsxco is larger than the output voltage Vsco (YES in step **S1101**), it is judged in step **S1103** whether or not the selected grid voltage V_G and the selected developing bias voltage V_B are the maximum values. If the selected grid voltage V_G and the selected developing bias voltage V_B are the maximum values (YES in step **S1103**), the grid voltage V_G and the developing bias voltage V_B can not be heightened, and therefore, the warning LED **251** is turned on in step **S1104**. Thereafter, the program flow goes to step **S1111** of FIG. **22***b*. On the other hand, if the output voltage Vsxco is equal to or smaller than the output voltage Vsco (NO in step **S1101**) or the selected grid voltage

V_G and the selected developing bias voltage V_B are not the maximum values (NO in step S1103), the program flow goes to step S1102, and then, it is judged whether or not the output voltage Vsxco is smaller than the output voltage Vsco. If the output voltage Vsxco is smaller than the output voltage Vsco (YES in step S1102), the program flow goes to step S1105, and then, it is judged whether or not the selected grid voltage V_G and the selected developing bias voltage V_B are the minimum values. If the selected grid voltage V_G and the selected developing bias voltage V_B are the minimum values (YES in step S1105), the grid voltage V_G and the developing bias voltage V_B can not be lowered, and therefore, the warning LED 251 is turned on in step S1104. Thereafter, the program flow goes to step S1111 of FIG. 22*b*. Further, if the output voltage Vsxco is not smaller than the output voltage Vsco (NO in step S1102) or the selected grid voltage V_G and the selected developing bias voltage V_B are not the minimum values (NO in step S1105), the program flow goes to step S1111 of FIG. 22*b*.

Thereafter, as shown in FIG. 22*b*, first warning processes from step S1111 to S1116 upon forming an image of magenta are performed in manners similar to those of the processes from S1101 to S1106 shown in FIG. 22*a*, and then, the program flow goes to step S1121 of FIG. 22*c*.

Thereafter, as shown in FIG. 22*c*, first warning processes from step S1121 to S1126 upon forming an image of yellow are performed in manners similar to those of the processes from S1101 to S1106 shown in FIG. 22*a*, and then, the program flow goes to step S1131 of FIG. 22*d*.

Thereafter, as shown in FIG. 22*d*, first warning processes from step S1131 to S1136 upon forming an image of black are performed in manners similar to those of the processes from Sl101 to S1106 shown in FIG. 22*a*, and then, the program flow returns to the original routine.

FIG. 23 is a flow chart of the second warning process of the subroutine shown in FIG. 18.

Referring to FIG. 23, it is judged in step S1201 whether or not an absolute value of a difference between the output voltage Vsco of the AIDC sensor 203 after the shift of the above-mentioned relationship and the output voltage Vsxco thereof in the initial state is larger than a predetermined threshold value ΔVs upon forming an image of cyan. If the absolute value thereof is larger than the predetermined threshold value ΔVs (YES in step S1201), it is necessary to increase the shift amount of the output voltage Vs in the table, however, the shift amount thereof is limited in the present preferred embodiment, as described above. Therefore, the program flow goes to step S1205, the warning LED 252 is turned on, and then, the program flow goes back to the original routine. On the other hand, if the absolute value thereof is not larger than the predetermined threshold value ΔVs (NO in step S1201), the program flow goes to step S1202.

Thereafter, it is judged in step S1202 whether or not an absolute value of a difference between the output voltage Vsmo of the AIDC sensor 203 after the shift of the above-mentioned relationship and the output voltage Vsxmo thereof in the initial state is larger than the predetermined threshold value ΔVs upon forming an image of magenta. If the absolute value thereof is larger than the predetermined threshold value ΔVs (YES in step S1202), the program flow goes to step S1205, the warning LED 252 is turned on, and then, the program flow goes back to the original routine. On the other hand, if the absolute value thereof is not larger than the predetermined threshold value ΔVs (NO in step S1202), the program flow goes to step S1203.

Thereafter, it is judged in step S1203 whether or not an absolute value of a difference between the output voltage Vsyo of the AIDC sensor 203 after the shift of the above-mentioned relationship and the output voltage Vsxyo thereof in the initial state is larger than the predetermined threshold value ΔVs upon forming an image of yellow. If the absolute value thereof is larger than the predetermined threshold value ΔVs (YES in step S1203), the program flow goes to step S1205, the warning LED 252 is turned on, and then, the program flow goes back to the original routine. On the other hand, if the absolute value thereof is not larger than the predetermined threshold value ΔVs (NO in step S1203), the program flow goes to step S1204.

Thereafter, it is judged in step S1204 whether or not an absolute value of a difference between the output voltage Vsko of the AIDC sensor 203 after the shift of the above-mentioned relationship and the output voltage Vsxko thereof in the initial state is larger than the predetermined threshold value ΔVs upon forming an image of black. If the absolute value thereof is larger than the predetermined threshold value ΔVs (YES in step S1204), the program flow goes to step S1205, the warning LED 252 is turned on, and then, the program flow goes back to the original routine. On the other hand, if the absolute value thereof is not larger than the predetermined threshold value ΔVs (NO in step S1204), the program flow goes to the original routine, directly.

In the foregoing description of the embodiment, in the case where the characteristic curve 401 in the initial state of the relationship between the output voltage Vs of the AIDC sensor 203 and the image density ID changes to, for example, the characteristic curve 402 as shown in FIG. 7, the grid voltage V_G and the developing bias voltage V_B in the V_G and V_B table are respectively shifted so as to obtain a desirable proper image density. However, the present invention is not limited to this, and the following image density control process may be performed when the characteristic shown in FIG. 7 is shifted from the initial characteristic curve 401.

(a) When a gain of the AIDC sensor 203 is lowered as shown in FIG. 8 and then the characteristic shown in FIG. 7 changes from the initial characteristic curve 401 to the characteristic curve 403, the gain thereof may be increased so as to return to a characteristic curve substantially close to the original initial characteristic curve 401.

(b) When an image density of a printed image of an original is about 0.1 and the printed image has an image density smaller than an original density of the original, the output power of the laser diode 221 may be increased. On the other hand, when the printed image has an image density larger than an original density of the original, the output power of the laser diode 221 may be decreased.

(c) When a printed image of an original has an image density larger or smaller or than an original density of the original, there may be changed the grid voltage V_G and the developing bias voltage V_B which are used when the reference test pattern image is formed. For example, when the image density is approximately 0.3 and the printed image has an image density smaller than an original density of the original, the grid voltage V_G is lowered, for example, from 650 V to 500 V, and also, the developing bias voltage V_B is lowered from 400 V to 250 V. On the other hand, when the printed image has an image density larger than an original density of the original, the grid voltage V_G is heightened, for example, from 650 V to 800 V, and also, the developing bias voltage V_B is heightened from 400 V to 550 V.

(d) When a printed image of an original has an image density smaller or larger than an original density of the original, there may be changed the output light amount of the laser diode **221** when the reference test pattern image is formed on the photoconductive drum **41**. For example, if an image density of a printed image of an original is about 0.1 and the printed image has an image density smaller than an original density of the original, the output light amount of the laser diode **221** is lowered, for example, from 110 to 90. On the other hand, if the printed image has an image density larger than an original density of the original, the output light amount of the laser diode **221** is heightened, for example, from **110** to **130**.

(e) In the case where a shift amount is relatively small when the characteristic for representing the relationship between the output voltage Vs of the AIDC sensor **203** and the image density is shifted, for example, from the initial characteristic curve **401** to a characteristic curve **411** as shown in FIG. **9**, the image density control process of the present preferred embodiment is performed. However, in the case where a shift amount is relatively large when the characteristic for representing the relationship between the output voltage Vs of the AIDC sensor **203** and the image density is shifted, for example, from the initial characteristic curve **401** to a characteristic curve **412** as shown in FIG. **9**, the following image density control process may be performed.

When a shift amount between the output voltage Vsxo of the AIDC sensor **203** to be shifted and the initial output voltage Vso is equal to or larger than 0.4 V, the temperature and the humidity are detected automatically by the temperature and humidity sensor **205**, and the output voltage of the transfer charger **52** is heightened based on the detected temperature and humidity. Thereafter, the AIDC correction process of the present preferred embodiment is performed again.

As described above, according to the present preferred embodiment of the present invention, in an image density control apparatus for performing the image density control process for controlling an image density of a reproduced image based on the output of detection means such as the AIDC sensor **203** for detecting a light amount of a reflected light from a toner image, there can be obtained a reproduced image having a desirable proper image density even if the relationship between the output of the detection means and the image density is shifted from that in the initial state when shipping the image forming apparatus from the factory, the original image can be reproduced with proper image density.

Although the present invention has been fully described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims unless they depart therefrom.

TABLE 1

Table No.	Output voltage Vs (V) of AIDC sensor	Grid voltage V_G (V)	Developing bias voltage V_B (V)
1	$0.4 < Vs \leqq 0.6$	900	650
2	$0.6 < Vs \leqq 0.8$	850	600
3	$0.8 < Vs \leqq 1.0$	800	550
4	$1.0 < Vs \leqq 1.2$	750	500
5	$1.2 < Vs \leqq 1.4$	700	450
6	$1.4 < Vs \leqq 1.6$	650	400
7	$1.6 < Vs \leqq 1.8$	600	350
8	$1.8 < Vs \leqq 2.0$	550	300
9	$2.0 < Vs \leqq 2.2$	500	250
10	$2.2 < Vs \leqq 2.4$	450	200

TABLE 2

Table No.	Output voltage Vs (V) of AIDC sensor	Grid voltage V_G (V)	Developing bias voltage V_B (V)
1	$0.4 < Vs \leqq 0.6$	1000	750
2	$0.6 < Vs \leqq 0.8$	950	700
3	$0.8 < Vs \leqq 1.0$	900	650
4	$1.0 < Vs \leqq 1.2$	850	600
5	$1.2 < Vs \leqq 1.4$	800	550
6	$1.4 < Vs \leqq 1.6$	750	500
7	$1.6 < Vs \leqq 1.8$	700	450
8	$1.8 < Vs \leqq 2.0$	650	400
9	$2.0 < Vs \leqq 2.2$	600	350
10	$2.2 < Vs \leqq 2.4$	550	300

What is claimed is:

1. An image forming apparatus for forming an image on a sheet of paper, comprising:

- an image retaining member;
- image forming means for forming a reference toner image on said image retaining member;
- first detection means for detecting a density of said reference toner image formed on said image retaining member and outputting first density data for representing the detected density thereof;
- transfer means for transferring said reference toner image formed on said image retaining member onto a sheet of paper;
- second detection means for detecting a density of said reference toner image transferred on said sheet of paper and outputting second density data for representing the detected density thereof; and
- adjustment means for automatically adjusting an image density of an image formed on a sheet of paper so as to obtain a predetermined image density by controlling operation conditions of said image forming apparatus based on said first and second density data respectively outputted from said first and second detection means.

2. The apparatus as claimed in claim **1**, wherein said second detection means is an image reader for reading an image of an original to be formed on a sheet of paper.

3. The apparatus as claimed in claim **1**, wherein said image forming means includes:

- a corona charger for electrically charging said image retaining member uniformly with an variable output value thereof;
- a developing device for developing an image formed on said image retaining member using toner with a developing bias voltage so as to form a toner image thereon; and
- a power source for applying a predetermined developing bias voltage, and

said adjustment means alters the output value of said corona charger and the developing bias voltage outputted from said power source based on said first and second density data respectively outputted from said first and second detection means.

4. An image forming apparatus for forming an image on a sheet of paper, comprising:

an image retaining member;

image reading means for reading an image of an original to be formed;

image data output means for converting the image of the original read by said image reading means into image data for representing a density of the read image and outputting the converted image data;

latent image forming means for forming an electrostatic latent image on said image retaining member based on the image data outputted from said image data output means;

developing means for developing the electrostatic latent image on said image retaining member with toner so as to form a toner image thereon;

first detection means for detecting a density of said toner image formed on said image retaining member and outputting first density data for representing the detected density thereof;

storage means for storing plural operation conditions of said latent image forming means and said developing means to be set for reproducing an image having a predetermined density, corresponding to the density of the toner image formed on said image retaining member;

reference latent image forming means for forming a reference electrostatic latent image on said image retaining member;

second detection means for detecting a density of a reference toner image after developing the reference electrostatic latent image formed on said image retaining member so as to form the reference toner image thereon by said reference latent image forming means, and outputting second density data for representing the detected density thereof;

adjustment means for selectively executing either one of:

a process of a first image density adjustment mode for reading out desirable operation conditions from said storage means based on the first density data outputted from said first detection means, and controlling said latent image forming means and said developing means to automatically adjust an image density of an image formed on a sheet of paper so as to obtain a predetermined image density, based on the read operation conditions; and

a process of a second image density adjustment mode for changing a correspondence relationship between the operation conditions stored in said storage means and the density of the toner image of the first density data outputted from said first detection means into another correspondence relationship therebetween, based on the image data outputted from said image data outputted means and the second density data outputted from said second detection means;

wherein the image of the original read by said image reading means is an image reproduced by transferring the reference toner image formed on said image retaining member onto a sheet of paper.

5. The apparatus as claimed in claim 4, wherein said adjustment means judges whether or not a difference between the image data outputted from said image data output means and predetermined reference image data is larger than a predetermined value, and executes the process of said second image density adjustment mode when judging that the difference therebetween is larger than the predetermined value.

6. The apparatus as claimed in claim 5, wherein, in the process of the second image density adjustment mode, said adjustment means corrects the second density data outputted from said second detection means based on a difference between the image data outputted from said image data output means and the second density data outputted from said second detection means, and alters contents of the operation conditions stored in said storage means based on said corrected second density data.

7. The apparatus as claimed in claim 6, further comprising:

further storage means for storing the second density data in an initial state of said image forming apparatus;

judging means for judging whether or not a difference between the second density data corrected by said adjustment means and the second density data stored in said further storage means is larger than a predetermined value; and

warning means for warning an operator when it is judged by said judging means that the difference between the second density data corrected by said adjustment means and the second density data stored in said further storage means is larger than the predetermined value.

8. An image forming apparatus for forming an image on a sheet of paper, comprising:

an image retaining member;

a further image retaining medium different from said image retaining member;

first image forming means for forming a reference toner image having a predetermined density on said image retaining member;

first detection means for detecting a density of said reference toner image formed on said image retaining member and outputting first density data for representing the detected density thereof;

second image forming means for forming a reference toner image having a predetermined density on said further image retaining medium;

second detection means for detecting a density of said reference toner image formed on said further image retaining medium and outputting second density data for representing the detected density thereof; and

adjustment means for automatically adjusting an image density of an image formed on a sheet of paper by controlling operation conditions of said image forming apparatus based on said first and second density data respectively outputted from said first and second detection means.

9. An image forming apparatus for forming an image on a sheet of paper, comprising:

an image retaining member;

a further image retraining member different from said image retaining member;

first image forming means for forming a reference toner image having a predetermined density on said image retaining member;

first detection means for detecting a density of said reference toner image formed on said image retaining member and outputting first density data for representing the detected density thereof;

first adjustment means for automatically adjusting operation conditions on said image forming apparatus based on said first density outputted from said first detecting means;

second image forming means for forming a reference toner image having a predetermined density on said further image retaining medium;

second detection means for detecting a density of said reference toner image formed on said further image retaining medium and outputting second density data for representing the detected density thereof; and

second adjustment means for automatically adjusting operation conditions of said image forming apparatus based on said first and second density data respectively outputted from said first and second detection means.

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